ECONOMIC EVALUATION OF PROTECTION AGAINST FREEZES IN SATSUMA MANDARIN PRODUCTION

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ECONOMIC EVALUATION OF PROTECTION AGAINST FREEZES IN SATSUMA MANDARIN PRODUCTION

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ECONOMIC EVALUATION OF PROTECTION AGAINST FREEZES IN SATSUMA MANDARIN PRODUCTION

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Jeanne (Williams) K. Lindsey, daughter of Thomas Sewell Williams and Patricia Caylor Williams, was born June 6, 1957 in New Orleans, Louisiana. She is a graduate of Saint Mary's Dominican High School in New Orleans. She earned a Bachelor of Science degree and a Master of Science degree in Horticulture from Auburn University in August, 1979, and March, 1982, respectively. In 1998, she received the Charter Life Underwriter designation from The American College in Bryn Mawr, Pennsylvania and she is a past president of the Columbus, Georgia Chapter of the Society of Financial Service Professionals. Work experience includes fruit research as a Research Associate for Auburn University; landscape contracting, design, and nursery management as the owner of Classic Designs; and insurance and financial product sales as a representative for Prudential Financial. She is currently employed by the US Department of Agriculture in the Risk Management Agency as a Risk Management Specialist. She is married to John F. Lindsey, Jr., the son of Reverend John Frank Lindsey, Sr. and Juanita Fuller Lindsey, and has three children, Stacia Marie Knowles, Eric Daniel Lindsey, and Katherine Lee Lindsey.

DISSERTATION ABSTRACT

ECONOMIC EVALUATION OF PROTECTION AGAINST FREEZES IN SATSUMA MANDARIN PRODUCTION

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This dissertation consists of three essays that evaluate the effect of freeze-risk reduction techniques on discounted net returns for Satsuma mandarin (*Citrus unshiu* Marc.) in the northern Gulf Coast region of the United States. In all studies, enterprise budgets are simulated over a 20-year investment horizon. Mean and distribution of net returns, and break-even prices are used to compare risk reduction methods. The first essay evaluates the effect of multi-peril crop insurance and freeze protection with micro-sprinkler irrigation on discounted net returns for one-acre grove units. Using weather data from the period 1948-2004, freeze occurrence probabilities for the Fairhope, Alabama area were calculated to be 14-percent for severe freeze and 11-percent for moderate freeze. Freeze protection in combination with crop insurance resulted in the highest mean and lowest variability in net return at market prices above break even. Increased yields and net returns due to freeze protection were attributed to the elimination of the need to replant after a severe freeze. Government subsidy for crop insurance premiums increased total discounted net returns; and indemnities lowered the distribution of negative net returns for the 20-year simulation period. In the second essay, micro-sprinkler and high tunnel technologies for freeze protection are compared to no protection for 10-acre Satsuma groves in the Fairhope, AL area. Micro-sprinkler technology eliminates the tree loss, but not crop loss, due to freezes. High tunnel technology eliminates the loss of either trees or crop for any freeze event. Relative to the high tunnel groves, average yield over the 20-year period was reduced by 25-percent for micro-sprinkler irrigated groves and 53-percent for unprotected groves. The high tunnel strategy was preferred to the micro-sprinkler protection only at market prices above $0.83 per pound. In the third essay, net returns for groves with micro-sprinkler and high tunnel technologies were compared to no protection at varying freeze probability levels. With severe freeze probability levels of 5-percent and greater, net returns for micro-sprinkler groves were greater than for unprotected groves. At a market price of $0.50 per pound, high tunnel groves had greater mean net returns than the micro-sprinkler technology only when total freeze events exceeded 50-percent.

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CHAPTER 1. EVALUATION OF NET RETURNS TO FREEZE PROTECTION AND CROP INSURANCE FOR SATSUMA MANDARIN USING MONTE CARLO SIMULATION

1.1 Introduction

Specialty crops offer agricultural producers the opportunity to increase net returns per acre relative to traditional crops. Returns may increase because of price premiums associated with niche markets or lack of competition. In many investment areas, higher returns are often associated with increased risk or uncertainty; production of specialty crops is no exception.

Methods chosen for risk mitigation depend on the type of risk. Evaluation of possible risk management techniques is important to enable producers to make good management decisions concerning which method, if any, to employ. Initial investment decisions may depend on the whether the risks can be economically managed. This is particularly important for perennial fruit crops that require significant investment and several years of growing time before positive returns are realized.

For the present study, the specialty crop chosen is Satsuma mandarin, a type of citrus that is grown in the United States in the northern Gulf Coast area, from Texas to Florida, and in Arizona and California. The primary production risk facing this crop is the risk of freeze injury. This paper will use Monte Carlo simulation to evaluate several possible risk management techniques for managing freeze risk in this crop in the Alabama area.

1.2 Review of Literature

1.2.1 Satsuma Mandarin

Satsuma mandarin (*Citrus unshiu* Marc.) is one of the most cold-tolerant citrus species available for commercial production in the US. The fruit characteristics of this species have been studied by Ebel, et al. (2004) and include sweet flavor, ease of peeling, and seedlessness. Consumer preference surveys have demonstrated that these characteristics are desirable to potential consumers (Campbell, et al., 2004).

Satsuma quality, both internal sugar-to-acid ratio and external orange color development, benefit from cool temperatures in the fall (Ebel, et al., 2004). Fruits mature between mid-October and mid-December. While fruit may be held on the tree longer than this, marketing is best done during the holiday season when the highest prices can be obtained. The Gulf Coast area of the United States is desirable for production because the warm temperate zone growing conditions allow for good tree growth and the relatively cool fall temperatures allow for good fruit quality development.

The southern part of Alabama has a long history of Satsuma production (Ebel, et al., 2004), as they have been produced there since the early 1900's. However, a once-viable citrus industry was decimated by killing freezes in the 1930's and 1940's (Winberg, 1948a, 1948b, 1948c). Recent developments in micro-sprinkler freeze protection have mitigated the risk to Satsuma due to freeze loss (Nesbitt, et al., 2000). This development and the absence of serious freeze events in the area since 1989 have contributed to revived interest in commercial production of Satsuma in the lower-Alabama area (Ebel, et al., 2005).

Based on historical levels of tree acclimation to cold in this region, the threshold for economically important injury is between 18 and 22 °F (-7 to -5 °C) (Ebel, et al., 2005; Nesbitt, et al., 2000; Nesbitt, et al., 2002). At 14 °F (-10 °C), stem dieback will occur and whole trees are susceptible to death if they are not fully hardened off. Temperatures below 12 °F (-11 °C) have historically resulted in tree death for unprotected trees. During a freeze event, micro-sprinklers placed within the tree canopy will protect the trunk and major scaffold branches through the release of the latent heat of fusion as the water spray freezes (Nesbitt, et al., 2000). This method of freeze protection decreases the severity of the freeze injury to the tree and prevents tree death. In the south Alabama region, freeze protected trees that experienced extensive injury to the canopy were able to return to full production the year following the freeze event (Nesbitt, et al., 2000). Because micro-sprinkler freeze protection does not extend to the outer canopy, freeze events that cause injury to leaves, or leaves and stems, will have the same effect on both protected and unprotected mature trees. Freeze events that could potentially kill unprotected trees, will have a lesser impact on freeze-protected trees. The protected trees will miss a year of production while canopy re-growth occurs, but the grove will not need to be replanted: (Bourgeois and Adams, 1987; Bourgeois, Adams, and Stipe, 1990; Nesbitt, et al., 2000).

1.2.2 Freeze Risk

While Satsuma are the most cold tolerant among commercial citrus crops, the single greatest risk factor facing potential growers of this citrus in the northern Gulf Coast region of the southeastern US is the risk of tree injury or tree death due to freezing weather. The second greatest risk factor is crop loss due to freeze injury to leaves, flowers, or flower stems. The use of micro-sprinklers within a tree canopy has been found to be an effective method of reducing tree loss due to freeze for citrus (Ebel, et al., 2004). During a severe freeze event, this type of protection system would protect the citrus trees from dying, but it would not prevent the loss of the next season's crop (Ebel, et al., 2005).

A study of damaging freeze events in Baldwin County, Alabama during the period of October 1948 to March 2004 found that there were 8 years in which severe freeze events occurred and six additional years in which only moderate freeze events occurred (Ebel, et al., 2005). A severe freeze was classified as one that caused extensive tree injury or tree death, and a moderate freeze was classified as one that caused extensive leaf injury and some stem dieback to the extent that the next season's fruit crop was destroyed. Based on this information, the long-term probability of severe freeze is 14-percent and moderate freeze is 11-percent. (Note: If both a severe and moderate freeze event occurred in the same growing period, only the severe freeze was counted for probability calculation purposes.) During the 1948-2004 period in this region, all freeze events occurred between the 12th of December and the 9th of March when mature fruit would not typically be present on the trees or most fruit would have been already harvested.

1.2.3 Risk Management and Evaluation Methods

Producers have various methods for managing the risks they face. Production and management practices such as grove site location, fertilization practices, and the use of freeze protection systems can have an effect on production risk and variability of returns for a grove. Marketing strategies can affect price risk.

Another method of risk mitigation used by many agricultural producers is Federal Crop Insurance. Market insurance is a risk transfer method that reduces the effects of economic loss on an insured's net revenue but it does not change the probability of a loss occurring (self-protection or risk avoidance) or reduce the severity of a loss (self-insurance or risk reduction) (Ehrlich and Becker, 1972). Installation of a freeze protection system, as used in this study, is primarily a self-insurance measure; the system will not affect the probability of a freeze occurring but will reduce the amount of tree injury resulting from a severe freeze. The use of crop insurance by a producer is a market insurance method of risk management.

Provision of crop insurance protection for specialty crops is currently a priority for the USDA Risk Management Agency (USDA, Risk Management Agency, 2004). A Satsuma crop insurance program for fruit or trees is not in place for south Alabama. If a named peril policy was available, however, it could mitigate the negative economic impact caused from a moderate or severe freeze by providing funds to replant or to help pay fixed and direct costs during years when trees or the crop is lost. (Note: disaster assistance is available through NAP – Noninsured Crop Disaster Assistance Program – for crops in counties without an insurance program. This program is administered through the Farm Service Agency of USDA but it is not included in the present evaluations.)

Various techniques have been used by researchers to evaluate risk and uncertainty in agricultural production including mean-variance models, linear programming, and simulation. A mean-variance linear programming model, considering changes in marginal benefits, was used by Featherstone and Moss (1990) to evaluate diversification opportunities for Florida citrus growers. MOTAD, a linear programming model that minimizes total absolute deviation from a mean rather than minimizing variance was used to evaluate optimal mixes of citrus types and planting density in Texas (Teague and Lee, 1988). When MOTAD was used in combination with simulation to evaluate production and marketing strategies on net farm income in Oklahoma, Mapp, et al. (1979), found that the simulation model was able to evaluate interactions of stochastic variables between years that were not possible with the MOTAD model. Simulation techniques were also used in combination with the Dixit-Pindyck model to evaluate investment behavior and sources of risk for grapefruit producers in Texas (Elmer, et al., 2001). Using these techniques, Elmer et al. determined that freeze risk was a greater source of uncertainty facing Texas grapefruit producers than market prices or expanded trade effects associated with NAFTA.

1.3 Data and Methodology

Data collected for this study includes yield records, production costs and historical temperature records. Yield data for an 'Owari' Satsuma mandarin grove was collected by the Alabama Agricultural Experiment Station Gulf Coast Research and

Extension Center at Fairhope, Alabama. Yield data spans 16 years from initial planting in 1990 through crop harvest 2005-06. In the simulations, the planting density assumption is 116 trees per acre. Trees are assumed to have no yield for the first two growing seasons and reach a maximum yield of 400 lb/tree (23.2 tons/acre) by the ninth growing season (Table 1).

1.3.1 Production Budget

Production costs were obtained from a Satsuma enterprise budget developed by Hinson and Boudreaux (2006) for Louisiana producers. Alabama producers are expected to have similar production methods and costs. The production budget includes costs for all labor and materials, as well as fixed costs of machinery and packing line equipment (Appendix Tables A2 and A3). Charges for a drip irrigation system are included in the simulation budget but were not in the Louisiana budget. Land is assumed to be an appreciable asset and there is no land charge included in the budget.

Tree yields, and fixed and direct production costs vary by the age of the tree and are presented in Table 1. Yield related costs of fruit harvest, grading, and packaging are calculated based on yield level and the presence of a crop; the variable harvest costs used in the simulation are $6.40 per 40 lb bushel and the direct harvest costs are $211 to $215 per acre (Appendix Table A3).

Freeze protection costs were developed from information supplied by the Gulf Coast Research Center and are presented in Appendix Table A3. The freeze protection system modeled is a micro-sprinkler irrigation system with one emitter per tree situated in the canopy at 5 feet above ground. Emitter delivery rate used is 30-gph. The study is modeled using one 4” well system with a 60-gpm capacity for each acre. It is important to note that, during a freeze event, the systems must operate simultaneously and continuously for all acreage to be protected. The cost of freeze protection is $6,350 per acre covers a 4-inch well, a 60-gpm pump, and all below ground pipes; these costs are amortized at 6-percent over the 20-year period. In addition, above ground pipes and emitters have a cost of $185 and they are replaced every 4 years (amortized at 6-percent over each 4 year period), and there is a $25 per year maintenance charge. With these assumptions, the total cost of freeze protection charge is $632 per acre per year.

Table 1. Values Used in Simulations That Change with Tree Age

		Tree Age - Growing Season								
Variable	Unit	1	2	3	4	5	6	7	8	9+
Yield	lb/tree	0	0	70	120	190	250	350	350	400
Fixed & Direct Costs										
Production	$/acre	2141	1157	1363	1693	1813	1813	1813	1813	1813
Harvest and Packing	$/acre	0	0	211	211	215	215	215	215	215
Tree Policy Indemnity[a]	$/acre	899	1634	2179	2451	2723	2723	2723	2723	2723

[a] Texas 2008 Citrus I tree policy with 65-percent coverage level.

Sources: Hinson, et al., Louisiana Agricultural Experiment Station Info. Series No. 140, 2006.
Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center, Fairhope, Alabama.

1.3.2 Crop Insurance Policies

Two hypothetical crop insurance policies were modeled after existing policies and actuarial tables for citrus trees in Cameron County, Texas, and for mandarin fruit in Riverside County, California (USDA-RMA, 2007a, 2007b, and 2007c). Values for these policies that were used in calculations for the simulations are presented in Appendix Table A1. The tree policy used values from the Texas Citrus I policy. This policy has a fixed liability per acre with a graduated indemnity rate that reaches its maximum if loss occurs during the fifth and subsequent growing seasons as presented in Table 1 and Appendix Table A1. The graduated indemnity schedule reflects an assumed decrease in risk of tree injury due to freeze as the trees mature. In the simulations, the grove was planted in March of the first year or in any re-plant year. The policy period is from November 21 to November 20 and there is never an insurance premium due for the tree policy in the initial year of the simulation because and there is no chance of a freeze event in the first year.

The fruit crop insurance policy in the simulation uses values for mandarins from the Arizona-California Citrus policy and a 65-percent coverage level. In this policy, the grove cannot be insured until the sixth growing season. The liability per acre is more complicated to calculate for this policy as it depends on the past yield performance of the insured grove, termed "actual production history" (APH). The APH is an average from the yield database containing a minimum of 4, building to 10, years. If there are less than 4 years in the database, a transitional-yield (T-yield) may be substituted for the missing yield; if there is a covered weather-related loss, a yield adjustment (YA) will substitute 60-percent of the T-yield for the lost yield in the database (USDA-RMA, 2006). In the liability calculation, the APH is multiplied by the coverage level and then by the price per unit (25-lb carton for this policy) assigned by RMA each year. With these assumptions, the liability calculation is:

(1) Liability = APH x Price Election x Coverage Level.

Premium rates for the tree and fruit crop insurance policies in Texas or California could not be used for these scenarios because of differences in freeze risk exposure

(Elmer, et al., 2001). The Risk Management Agency rate setting procedures are normally based on county/state indemnity experience for a particular crop (Schnapp, et al., 2000). Without any indemnity history, different methods need to be employed to determine a rate. In this study, base insurance premiums were calculated to produce a 1.00 premium to loss ratio based on the simulated loss experience with the given freeze probabilities. A catastrophic load was added to the base premium by dividing it by .88. The insured grove was assumed to have only one unit. With these assumptions, and the deduction of the appropriate government subsidy, a producer premium of $155 per acre was calculated for a 65-percent coverage level for the tree policy.

For the fruit crop insurance policy, the total base premium rate of $0.313 was calculated using procedures described above. Premiums were charged to the appropriate simulation grove in the sixth and subsequent years. Producer premiums for each insured year in the simulation were calculated with the following equation:

(2) Producer Premium = (Liability x base rate) – subsidy;

where the appropriate subsidy rate for the 65-percent coverage level in 59-percent of the calculated premium.

1.3.3 Freeze Probability and Models

Daily min-max temperature data from 1948 through 2006 was obtained from the weather station located at the Gulf Coast Research Center. Economically important freezes were determined through a prediction formula developed by Ebel, et al. (2005) and compared to field observations for severity rating. These ratings were used to calculate probabilities of economically damaging freeze occurrence in the Fairhope, Alabama area. Freeze severity ratings are: 1) Slight – some injury to leaves, 2) Moderate – extensive leaf injury and some stem dieback and 3) Severe – widespread tree death. Only moderate and severe freeze events are considered economically important in this study. Based on this information, the simulations use the severe freeze probability of 14-percent and the moderate freeze probability of 11-percent.

A hypothetical one-acre Satsuma grove was the unit of study. A Monte Carlo simulation with 100 iterations was performed using Excel 2003 for each of four scenarios for a 20-year period at each of seven different farm-level market prices ranging from \$0.20 per pound to \$0.50 per pound. The random event was the incidence of severe, moderate or no freeze. The generated random number matrix was consistent between scenarios. Net returns were calculated based on the costs and returns associated with the freeze event status and the tree age. The four scenarios were then evaluated based on discounted net returns totaled over the 20-year period and on the distribution of negative discounted 20-year net returns over the range of market prices. The scenarios evaluated were:

1) No freeze protection and no crop insurance (NP_NI),
2) Freeze protection and no crop insurance (P_NI),
3) No freeze protection plus crop insurance for tree loss (NP_I), and
4) Freeze protection plus crop insurance for fruit loss (P_I).

Without freeze protection, trees were assumed to lose one crop year if a moderate freeze occurs, and were assumed to die and to be replanted if a severe freeze occurs. The number of times the grove will be replanted in the simulated 20-year production periods is limited only by the severe freeze probability and the random draw of a severe freeze. The probability of a severe freeze occurring was set at 14-percent and the probability of a moderate freeze occurring is set at 11-percent based on historical data for the Fairhope, Alabama area. With freeze protection, trees were assumed to respond to both severe and moderate freezes with the loss of one crop year and no tree deaths ever occurred. A crop insurance policy insuring tree loss was considered more valuable to a producer when no freeze protection was present. A crop insurance policy insuring fruit production was considered more valuable to a producer when freeze protection was in place because there no tree loss occurred under this scenario.

The discounted total net returns equation for the base scenario NP_NI is:

$$(3) \qquad NR_d = \sum_{j=1}^{20} [(PY_j(f, t) - C_j(t) - X_j(y)) / (1+r)^j]$$

where NR_d = total discounted net returns, j = the simulation year, f = freeze event, t = tree age, P = market price for fruit, $Y_j(f, t)$ = yield in the jth year as a function of freeze event and tree age, $C_j(t)$= fixed and direct costs in the jth year as a function of tree age, and $X_j(y)$ = variable costs as a function of yield in the jth year, and r = the discount rate. This equation is modified for the different scenarios as follows:

$$(4) \qquad \text{P\_NI:} \qquad NR_d = \sum_{j=1}^{20} [(PY_j(f(cp), t) - C_j(t) - CP - X_j(y)) / (1+r)^j]$$

$$(5) \qquad \text{NP\_I:} \qquad NR_d = \sum_{j=1}^{20} [(PY_j(f, t) + I_j(f, t) - C_j(t) - CI_j - X_j(y)) / (1+r)^j]$$

$$(6) \qquad \text{P\_I:} \qquad NR_d = \sum_{j=1}^{20} [(PY_j(f(cp), t) + I_j(f) - C_j(t) - CP - CI_j - X_j(y)) / (1+r)^j]$$

where the terms described above are applicable and CP = the fixed cost of freeze protection, f(cp) = freeze event as a function of freeze protection, $I_j(f, t)$ = the insurance indemnity in the jth year as a function of freeze event and tree age, CI_j = cost of crop insurance policy in the jth year, and $I_j(f)$ = insurance indemnity in the jth year as a function of freeze event.

1.4 Results and Discussion

Discounted 20-year net returns for each of the scenarios are presented in Table 2 for market prices ranging from \$.20 per pound to \$.50 per pound. Breakeven prices of \$.258 to \$.291 per pound were calculated for the different scenarios with the lowest price being required by enterprises under the P_I scenario and the highest price being required under the NP_NI scenario. Below this cluster of breakeven prices, returns to freeze protection are less than returns to no freeze protection because of the large capital investment needed for the freeze protection system. Above the breakeven prices, however, the returns increase due to higher yields from protected groves.

Total net returns over the 20-year period have a positive relationship to market price with the magnitude of the response being dependent on yield, $\partial NR/\partial P = Y(f,t)$ (from equations (3) and (5)) or $\partial NR/\partial P = Y(f(cp),t)$ (from equations (4) and (6)). Yield is a function of freeze event and tree age; the severity of the freeze event changes in response to freeze protection measures, but not to insurance protection. Total yield will increase with freeze protection because, in the event of a severe freeze, protected trees lose only one year of production whereas unprotected trees must be replanted and it will take two years before the grove starts to become productive again.

Table 2. Discounted 20-Year Net Returns for Satsuma under Varying Risk Management Scenarios

	Scenario [a]			
Market Price $/lb	NP_NI	P_NI	NP_I	P_I
0.20	-14,437 (2,333)	-18,603 (1,350)	-12,456 (1,013)	-14,783 (1,689)
0.25	-6,525 (5,900)	-5,839 (3,291)	-4,544 (4,233)	-2,019 (1,416)
0.30	1,387 (9,475)	6,925 (5,233)	3,368 (7,773)	10,745 (2,950)
0.35	9,299 (13,052)	19,689 (7,175)	11,280 (11,336)	23,509 (4,791)
0.40	17,212 (16,629)	32,453 (9,117)	19,192 (14,907)	36,273 (6,689)
0.45	25,124 (20,207)	45,217 (11,060)	27,104 (18,481)	49,037 (8,607)
0.50	33,036 (23,785)	57,980 (13,002)	35,016 (22,056)	61,801 (10,534)
Price Intercept	0.291	0.273	0.279	0.258

[a] NP=no freeze protection, P=freeze protection, NI=no crop insurance, I=crop insurance.

Values in parentheses are standard deviations.

The observed price/yield relationships indicate that the groves with freeze protection will benefit more from an increasing market price situation than unprotected groves, which will have a lower 20-year yield. Slopes for the regression equations do not vary by crop insurance policy, but are 1.6 times greater under the freeze-protected scenario than under the unprotected scenario as shown in Figure 1.

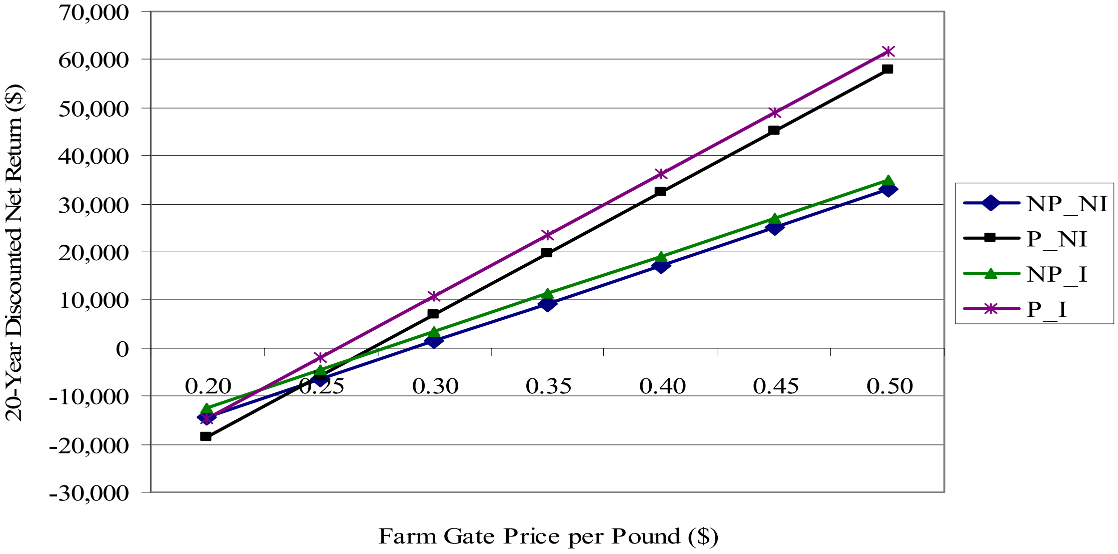

Figure 1. Response of Discounted 20-Year Net Returns to Market Price for Satsuma under Varying Risk Scenarios – Fairhope, Alabama

The two types of insurance policies cannot be directly compared because they have different indemnity schedules. However, they each have the same effect on total discounted net returns within protection scenarios with the tree policy resulting in an increased discounted net return of $1,980 over the 20-year period and the fruit policy resulting in an increase of $3,820 (Table 2). The returns to each crop insurance policy are consistent between market prices. The insurance policy net returns would be expected to be negative because the premiums were set to result in a .88 loss ratio; however, the positive net return reflects the government subsidy for premiums.

Since insurance is usually a negative sum game due to charges in excess of actuarially fair premiums (i.e. administrative costs, shareholder profits, catastrophic charges, etc.), its real value as a risk management tool results from its effect on income variability. Both insurance policies used in the simulations reduced the standard deviation of 20-year net returns under each protection scenario. The percentage change in standard deviations, when compared to the base scenario of no-protection/no-insurance, is presented in Table 3. When evaluated on a percentage basis, both the use of freeze protection and the use of crop insurance have a stabilizing effect on the variability of total discounted net returns. The effects from insurance decrease with increasing market price and increasing total net returns while the effects from freeze protection are relatively consistent across market price. The greatest decrease was seen in the scenario with the interaction of freeze protection and crop insurance.

A graph of the distributions of negative discounted 20-year net returns is illustrated in Figure 2. All risk management technique scenarios resulted in a decrease in the distribution of negative net returns at market prices of $.30 per pound and above. Freeze protection results in the greatest reduction with crop insurance having a lesser effect. The no-intervention scenario does not reach 0-percent negative net returns distribution given the market prices used in this study. Risk management using crop insurance reduces the variability of returns, but it does not allow producers to benefit from increasing market prices. The results of this study indicate that under increasing prices producers would be have higher net returns with the use of risk management techniques that allow a return to increased production. At zero-profit and very competitive prices, crop insurance may be better for reducing risk because of lower capital investment. The combination of crop insurance and freeze protection results in the greatest net returns and the lowest income variability at market prices above breakeven price. Installing freeze protection systems is costly in these scenarios with the initial investment for the system being three times greater than the initial investment for planting the Satsuma grove. However, if historical freeze event probabilities are indicative of future events, and market prices are higher than breakeven prices, then producers will benefit from freeze protection investment.

Table 3. Percentage Change in Standard Deviation of Discounted 20-Year Net Returns when Compared to Base Scenario[a]

	Scenario [b]		
Market Price $/lb	P_NI	NP_I	P_I
0.20	-42.1	-56.6	-27.6
0.25	-44.2	-28.3	-76.0
0.30	-44.7	-18.0	-68.9
0.35	-45.0	-13.1	-63.3
0.40	-45.2	-10.4	-59.8
0.45	-45.3	-8.5	-57.4
0.50	-45.3	-7.3	-55.7

[a] Base scenario is no-protection/no-insurance.

[b] NP=no freeze protection, P=freeze protection, NI=no crop insurance, I=crop insurance.

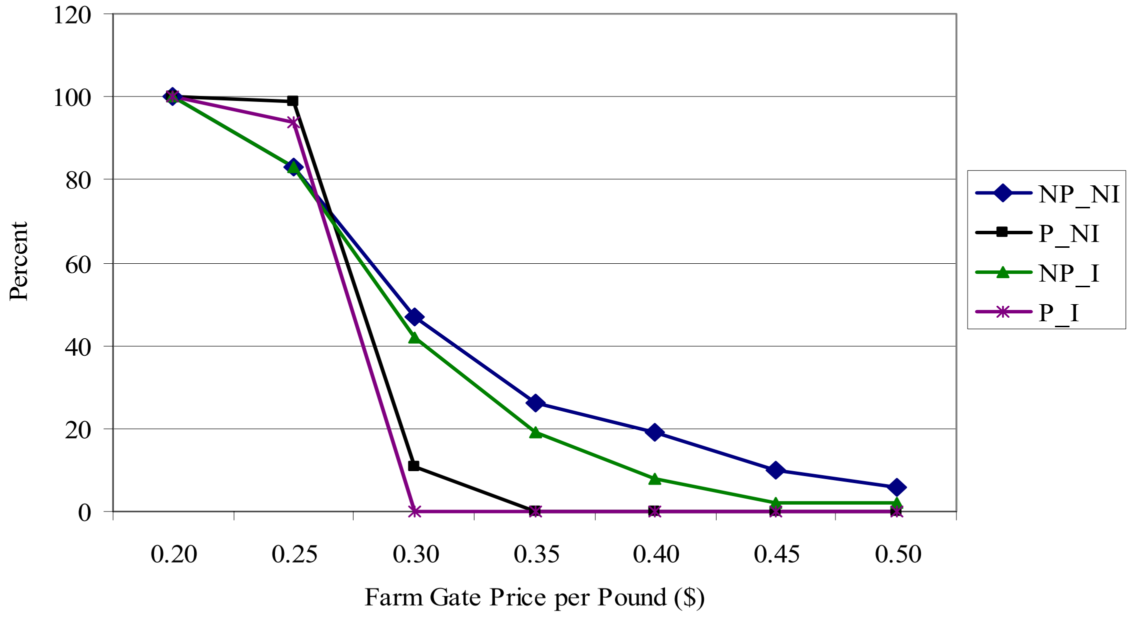

Figure 2. Distribution of Negative Discounted 20-Year Net Returns for Satsuma under Varying Risk Scenarios – Fairhope, Alabama

1.5 Conclusions

Freeze protection systems and crop insurance were the two risk reduction methods that were chosen for evaluation in this economic study. Each method has different effects on costs and returns because of grove responses to random freeze events. The objective of this empirical study was to evaluate the net returns to freeze protection and to crop insurance for Satsuma using a Monte Carlo simulation procedure. Information obtained from this study would be useful in the decision making process for current and potential Satsuma producers in the northern Gulf Coast region of the United States and to all enterprises facing decisions between the use of self-insurance measures and market insurance for risk management.

The results of this study indicate that under increasing prices producers would have higher net returns with the use of risk management techniques that allow a return to increased production. The 20-year net returns are greater for all risk reduction procedures when market prices are above breakeven price, with returns being greater to freeze protection than to crop insurance. Freeze protection measures allow the Satsuma enterprise to benefit from increasing prices because of increased yield over the 20-year period. Returns to crop insurance are fixed and do not increase with market price, however, the use of crop insurance decreased the variability of returns with a reduced standard deviation in discounted net returns and lower distribution of negative discounted net returns for the 20-year period. The combination of crop insurance and freeze protection resulted in the greatest net returns and the lowest income variability at market prices above breakeven price.

Installing freeze protection systems was costly in these scenarios with the initial investment for the system being three times greater than the initial investment for planting the Satsuma grove. However, with the freeze probabilities used in this study and market prices higher than breakeven prices, producers could benefit from freeze protection investment.

CHAPTER 2. EVALUATION OF PROTECTION TECHNOLOGIES FOR SATSUMA MANDARIN PRODUCTION IN ALABAMA WITH ENTERPRISE BUDGET SIMULATION

2.1 Introduction

In the Gulf Coast region of Alabama, as in many areas of the United States, development pressure on the conversion of farm land to residential and other urban-related uses is a major factor in rising land prices (Lubowski et al., 2006; USDA, NASS, 2007; Wiebe and Gollehon, 2006). Increasing the returns per acre may be an important factor in keeping land in agricultural production in these areas. Perennial tree crops generally return high profits per acre and offer an attractive alternative for growers who are willing to convert from traditional row crops. Higher returns, however, come at a cost as perennial crops generally have more intensive labor, management, and capital requirements than row crops and they may carry additional production risks.

As with any agricultural crop, production of perennial tree crops involves risks from many different sources. Decision makers must make risk reduction choices that are both effective and economically feasible given the operation's particular objectives, constraints, assets, and time horizons. In many cases, risk reduction may involve significant investment and the effects of stochastic variables on a multi-year operation complicate the decision process.

Ex ante analysis with simulation offers valuable information for decision makers before committing to significant initial investments (Purvis et al. 1995). Simulation is a decision making tool that allows for interaction between years that is not possible with standard linear programming models (Mapp et al., 1979). Simulation models can evaluate alternative strategies while incorporating risk to answer the positive question of what is the likely outcome (Richardson, 2004). Through the simulation of an enterprise budget, insight can be gained from the distribution of net returns, and other variables of interest, in addition to their expected values (Nelson et al., 2001).

Satsuma mandarin orange is a perennial crop that could potentially provide a high value alternative for agricultural producers in the northern Gulf Coast region of the United States. In Alabama, this area encompasses Baldwin and Mobile counties where there is growing interest in reviving a once viable Satsuma mandarin industry (Ebel et al., 2005). Research conducted by Auburn University on freeze protection of Satsuma provided the catalyst for the present economic study. Protection of plants from freeze, the primary risk factor, can be provided at different protection and cost levels. The economic consequences of the trade-off between risk-reduction and increased production costs have not been previously evaluated for Satsuma in this area. This information would be useful for current and potential producers to make investment decisions relating to the establishment of Satsuma groves and/or the installation of freeze protection.

The primary objectives of this study were to: 1) determine if the proposed freeze protection methods are economically feasible, 2) evaluate the effect of these freeze protection methods on the riskiness of net returns, and 3) conduct sensitivity analysis on key input variables for high tunnel technology. To achieve these objectives, enterprise budgets for three hypothetical Satsuma groves in south Alabama, with a 20-year investment horizon, will be simulated. Stochastic dominance was used to compare simulations with standard inputs. In the sensitivity analysis, break-even prices and equivalent prices were also compared. This paper will proceed with a review of the literature, a section on methodology to describe the data and the model, followed by presentation and discussion of the simulation results, and concluding remarks.

2.2 Review of Literature

2.2.1 Satsuma Mandarin

Satsuma mandarin (*C. unshiu* Marc.) is one of the most cold-tolerant of the commercial citrus species grown in the US (Hodgson, 1967). These citrus fruits have characteristics (sweetness, easiness of peeling, and seedlessness) which consumers find desirable (Campbell, et al. 2004). A thriving Satsuma mandarin industry existed in the Gulf Coast region of Alabama during the early 1900's until a succession of freezes around 1940 decimated the groves and later freezes discouraged replanting (Ebel, et al., 2004, 2005).

The re-development of a Satsuma industry in the Gulf Coast region of Alabama has been encouraged by a combination of factors. Technological developments in the use of micro-sprinkler irrigation within tree canopies have been successful in mitigating freeze risk in Satsuma in the Gulf Coast region (Bourgeois and Adams, 1987; Bourgeois et al., 1990; Nesbitt et al., 2000). Farmers in the counties of Baldwin and, to a lesser extent, Mobile, are facing increasing development pressure and increasing land prices (Lubowski et al., 2006; USDA, NASS, 2007; Wiebe and Gollehon, 2006). Maintaining active farms will require the production of high value crops as cropland becomes scarcer and farms are reduced in size. Nationally, there is also increased interest on the part of consumers to buy locally grown produce (Gray, 2005). This trend may contribute to future grower interest in Satsuma production for localized sales.

To facilitate the development of this industry, the USDA funded a multi-discipline research effort by Auburn University, in partnership with Louisiana State University, aimed at reducing production and marketing risk, and evaluating germplasm for potential use in breeding programs for Satsuma in Alabama and Louisiana. Current experimentation on freeze protection in Alabama includes the evaluation of high tunnels and the continued evaluation of micro-sprinklers for freeze protection. These two freeze protection methods are used as alternative strategies to the base plan with no protection in the simulation analysis of this paper.

2.2.2 Freeze Protection

Satsuma is one of the most cold hardy of the commercial citrus species grown in the United States. Leaves are more sensitive to cold injury than the stems or trunks, and the minimum air temperature that causes injury is dependant upon the duration of the freeze event and the level of tree acclimation to cold (Yelenosky, 1991; Ebel, et al., 2005). Many environmental and biological factors affect cold acclimation; however, air temperature preceding the freeze event in citrus is the most important factor (Yelenosky, 1985, 1991, 1996). To acquire maximum cold hardiness, requires exposure of the tree to air temperatures $\leq 50\ ^{o}$F ($10\ ^{o}$C) during the 500 hours (≈ 3 weeks) prior to the freeze event (Yelenosky, 1991). Based on historical levels of tree acclimation to cold in south

Alabama, the threshold for economically important injury occurs is between 22 and 18 °F (Ebel et al., 2005, Nesbitt et al., 2000; Nesbitt et al. 2002). This threshold represents the point where there is extensive leaf injury and some stem dieback such that the crop for the following harvest season is destroyed but the tree can recover and produce a normal crop the following year. At 14 °F (-10 °C), there is extensive injury to stems and the whole tree is susceptible to death if it is not acclimated to cold. Temperatures below 12 °F (-11 °C) have historically resulted in tree death for unprotected trees regardless of the level of cold acclimation. In the simulations for this study, a moderate freeze is considered to be one that causes the loss of the crop, but not the death of the tree. A severe freeze is one that causes injury to an unprotected tree to the point that the tree cannot recover.

There have been many methods of freeze protection employed in the production of citrus with no one method being completely effective for all types of freeze events (Martsolf, 2000; Powell and Himelrick, 2007). Only two methods of freeze protection were modeled in the present economic study. The first method involved the use of micro-sprinkler irrigation, with the assumption that trees would not die in the event of a severe freeze but there would be a loss of fruit in the event of either a moderate or a severe freeze. The second method modeled was the use of high-tunnel technology with an assumption of full protection for both the trees and fruit in the event of either severe or moderate freezes.

For the southern parts of Alabama and Louisiana, the use of micro-sprinkler irrigation within the tree canopies has been demonstrated to be effective in protecting tree trunks and major scaffold limbs during damaging freeze events (Bourgeois and Adams, 1987; Bourgeois et al., 1990; Nesbitt et al., 2000). This type of system does not protect the outer tree canopy, however, and the crop for the following growing season could be lost because leaves and stems are important for flower and fruit retention. In south Alabama, trees that experienced extensive injury to the outer canopy were able to return to normal production by the second growing season following the freeze event (Nesbitt et al., 2000).

During an entire freeze event, the micro-sprinkler irrigation system must apply water continuously to all trees in the grove. The primary mechanism providing protection is the release of latent heat of fusion, as water crystallizes into ice (Powell and Himelrick, 2007). The system must also be independent of electricity, which may be unavailable during some freeze events. The system requirements for freeze protection are much greater than those needed for a normal irrigation regime which can use low volume emitters and zonal controls. The well and pump systems required for the freeze protection system represent a significant investment on the part of the producer.

High tunnels are unheated, greenhouse-like structures with metal ribs covered with plastic. They are used extensively in Europe, Asia, and Israel to grow high-valued crops in areas with high population densities and constrained land and water resources (Orzolek, Lamont, and White, 2002). This technology was pioneered in the United States by Otho Wells, at the University of New Hampshire, and is now being tested for agricultural applications by several universities (Lamont, 2003). High tunnels are being used to extend growing seasons, increase quality, and reduce pesticide inputs. While relatively inexpensive when compared to traditional greenhouses, protecting plants with high tunnels adds significantly to establishment costs and can only be justified for high-value crops.

Auburn University currently has two high tunnel demonstrations with high-density plantings of Satsuma; one in the Gulf Coast region and one in the center of the state at the Chilton Area Horticultural Substation where there is an increased risk of freeze. The tunnels are 96 feet long and 24 feet wide and cover 30 trees each. The expectation for producing Satsuma under high tunnels is to totally eliminate fruit loss and tree death due to freeze.

The high tunnels are only covered during the winter months since they are only used for freeze protection. White polyethylene plastic is used to prevent greenhouse effects associated with clear plastic that would cause plants to deacclimate and become less cold tolerant, or to thaw too quickly in the event of freezing temperatures. High tunnels are designed so that the sides can be raised for ventilation, but the top stays in place. Plants are covered from December, after the threat of hurricanes, until March or April after the threat of freeze has passed. Irrigation with micro-sprinklers under the canopies is provided and the irrigation system can add some additional heat in the event of severe freeze; however, no other heat source was added to the high tunnels in the demonstrations.

2.3 Data and Methodology

2.3.1 Yield Data

Data evaluated for this study included yield records, production costs, and historical temperature records. Due to a lack of commercial production records, experimental yield data was used to develop an expected production curve by tree year. Yield data for an ‘Owari’ Satsuma mandarin grove was collected by the Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama from initial planting in 1990 through crop harvest 2006-07. While this data set is not ideal, as trees have been used in various experiments, information on the changes in yield by tree age can be estimated from the grove average yields and standard deviations. Trees are not allowed to have production for the first two growing seasons in order to maximize tree growth. Average production levels off around the 9th growing season and may exhibit biennial bearing in subsequent years (Ebel, et al., 2004). For the simulations, yield was assumed to increase from the third through the ninth year at which time an average production of 400 pounds per tree is reached and used as the mature average yield per tree (Appendix A1). To account for possible yield variation in early years and possible biennial bearing in later years, yields were modeled with ± 25-percent variation using the GRKS distribution for Simetar© that was developed by Gray, Richardson, Klose, and Schumann (Richardson, 2004). This distribution allows for the specification of the minimum, midpoint, and maximum values and approximately 95-percent of the simulated observations will fall between the minimum and the maximum and 50-percent are less than the midpoint. In addition, 2.2-percent of the observations will fall below the minimum and 2.2-percent will be above the maximum.

2.3.2 Yield Ratio

An important factor for comparing the different systems is the “yield ratio”. The yield ratio is defined as the ratio of the expected yield of one tree on trifoliate rootstock to the expected yield of one tree on dwarfing rootstock. The yield ratio can also be take to mean the number of trees on dwarf rootstock needed to equal the yield of one tree on conventional trifoliate rootstock. The trifoliate rootstock, 'Rubidoux' is used for both the non-protected and the micro-sprinkler freeze protected Satsuma groves with conventional plant spacing, and the dwarfing rootstock 'Flying Dragon' is used for the high tunnel freeze protected grove with high-density spacing. For the unprotected groves, a planting density of 116 trees per acre with Satsuma 'Owari' on 'Rubidoux' trifoliate orange rootstock was modeled. For the high-tunnel planting, a high-density tree spacing of 6 by 12 feet was used with 30 trees per tunnel with dimensions of 96 feet length and 24 feet width. To maintain trees within the confines of the high tunnels, Satsuma 'Owari' is grown on a dwarfing rootstock, 'Flying Dragon'. To compare the returns for the two different planting densities and plant sizes, the budgets were standardized on an equivalent yield basis. The "yield-ratio" reflects the expected yield from a conventional tree in relation to the expected yield from high-density tree on dwarfing rootstock. Conversely, it will also reflect the number of high density trees needed to produce the same yield as one tree on conventional-spacing and rootstock. The implications of the yield ratio are that the higher the ratio (minimum is 1.0), the more high-tunnel plantings needed to equal an acre of conventional-spacing trees, and the greater the cost of high tunnel freeze protection.

To determine an appropriate yield-ratio, Japanese research was consulted due to the lack of published yield data for the dwarfing rootstock, 'Flying Dragon', in the United States. Based on studies in Japan, and given their cultivars and growing conditions, a yield-ratio of 2.0 was estimated and used as the standard in the simulations (Takahara et al., 2001; Noda et al., 2001; Yonemoto et al., 2005). The accuracy of the translation of this yield-ratio to the 'Owari' cultivar under Alabama growing conditions will be determined in future years as the experimental groves mature.

2.3.3 Production Costs

General production costs were obtained from a Satsuma enterprise budget developed by Hinson, Boudreaux, and Vaughn (2006) for Louisiana producers. The Louisiana budget utilizes the Mississippi State Budget Generator for computations (Mississippi State University). All variable costs for labor and materials, and fixed costs for machinery and packing line equipment are included and are detailed in Appendix Tables A2 and A3. Land was not included in the Louisiana budget because of the many options for owning or obtaining the resource and users were instructed to adapt the budget to their own situation. In the current study, land was assumed to be an appreciable asset with the discounted terminal value equal to the initial value and no land charges were included in the budget. Alabama producers were expected to have production methods and costs similar to Louisiana producers. The Louisiana budget did not include costs for irrigation; however, irrigation charges for a micro-sprinkler system were included in all simulation scenarios in the study. The quantity of variable inputs differed between production systems and was influenced by freeze occurrence and severity, tree age, and cost of freeze protection modeled (Appendix Table A2). Fixed costs were amortized based on the schedule in Appendix Table A3 at 6-percent with zero salvage value. Fixed costs associated with grove establishment (planting) were treated as one-time costs in the year they were realized. For the unprotected grove simulations, re-establishment costs were realized any time that a severe freeze event occurred and the grove was replanted. The micro-jet and high tunnel simulations never had to re-establish groves.

Freeze protection costs were developed from information supplied by the Gulf Coast Research Center at Fairhope, Alabama. The micro-sprinkler freeze-protection system was modeled with one emitter per tree situated in the canopy at 5 feet above ground. Emitter delivery rate was 30-gph. Each acre required one 4-inch well system with a 60-gpm capacity pump. The total fixed cost of this system included 1) a well, pump, and all below ground pipes with a cost of $6,350 per acre, amortized at 6-percent over the 20-year period, and 2) above ground pipes, tubing, and emitters that are replaced every 4 years with a cost of $185 per acre, amortized at 6-percent over each 4-year period. In addition, there was a one-time installation charge of 25 labor hours per acre and there was an annual $25 per acre maintenance charge. With these assumptions, the annual fixed cost was $607 and the direct/variable cost was $25 for a total cost of $632 per acre for freeze protection after installation (Appendix Tables A2 and A3).

The high tunnel system fixed cost was $4,500 per tunnel and included construction materials for a 96 x 24 foot structure with two end walls and two layers of 20-year ground cloth for weed control. Forty labor-hours were required for assembly of each tunnel. The construction material cost was amortized at 6-percent over the 20-year period, but installation labor is given a one-time charge. Annual maintenance costs for each tunnel included a charge of $164 for the 6-mil white plastic with a two-year life, and 12 labor hours for replacement, maintenance, and removal of the plastic. With these assumptions, the annual fixed cost was $392 per tunnel and the direct/variable cost was

$279 per tunnel for a total cost of $671 per tunnel after installation (Appendix Tables A2 and A3). The number of tunnels with high-density plantings on 'Flying Dragon' rootstock needed to equal an acre of conventional plant spacing on 'Rubidoux' rootstock varied by the assumed yield-ratio.

2.3.4 Freeze Risk

Severe and moderate freeze events occur often enough in the Gulf Coast region of Alabama to introduce significant uncertainty into the production of cold-sensitive crops. In a study of the effect of freeze on Satsuma in the Baldwin County area, Ebel et al. (2005) compared daily min-max temperature data to reported tree injury for the period October 1948 through March 2004. During this period there were 8 years in which severe freeze events occurred and six additional years in which only moderate freeze events occurred. A severe freeze was classified as one that caused extensive tree injury or tree death. A moderate freeze was classified as one that caused extensive leaf injury and some stem dieback to the extent that the next growing season's fruit crop was destroyed, but trees were back to full production by the 2nd harvest season after the freeze. Based on this information, the long-term probability of a severe freeze in the Fairhope, AL area is 14-percent, and that of a moderate freeze is 11-percent. It is important to note that these two types of freeze event are, for our purposes, mutually exclusive; if both a severe and moderate freeze event occurred in the same growing period, only the severe freeze was counted. During the period of 1948-2004 in the Fairhope region, all freeze events occurred between the 12th of December and the 9th of

March when mature fruit would not typically be present on the trees or harvest would be near completion. For simplification in the simulation models, all freezes are assumed to occur at the beginning of the period (in winter after harvest of the previous growing season crop) and reduce the yield, as appropriate for the protection system, for the current growing season.

2.3.5 The Model

The basic unit of study was a hypothetical 10-acre Satsuma grove with a 20-year investment horizon. A Satsuma grove could potentially remain productive for more than the 20-year period, however, this time-period was chosen as the maximum time in which an investor could make meaningful comparisons between alternative scenarios. Using a 2.0 yield ratio between conventional and high-density plantings, 7.7 high tunnels were required to equal one acre of conventional production and the unit is referred to as "acre-equivalents" in the budgets. Thus the 10-acre-equivalent for high tunnels would be 77 tunnels. It should be pointed out that a whole number of tunnels was always used and that this may cause a few more or less trees to be included in the high tunnel grove than in the alternative groves depending upon the yield ratio used. The actual land requirement for high tunnel production will depend upon the placement of the tunnels; however, since land charges were not included in the budgets, the unit of land is of no consequence in the simulations.

Simulations were run for the hypothetical groves to compare three alternative production methods. These production methods will be identified in all further discussion as 1) "Unprotected" for the grove with no freeze protection, 2) "Micro-jet" for the grove with micro-sprinkler irrigation freeze protection, and 3) “High Tunnel” for the high-density grove protected with high tunnels.

Analysis of a multi-year operation is complicated by: 1) risk probabilities in multiple years which may be independent or correlated, 2) the impact that decisions and occurrences in one year have on decisions and outcomes in future years, and 3) input costs and average yields that vary with the age of the plant.

The simulations in this study approached these considerations in the following ways:

1) Freeze events were assumed to be independent across years. Each year of the operation, the occurrence of a freeze event followed a uniform (0,1) distribution with Latin Hypercube sampling (Inman, Davenport and Zeigler, 1980).

2) All freezes were assumed to occur at the beginning of a calendar year and affect the yield in the coming fall. For clarity, the effect of freeze events on yield is presented in Table 1. If no freeze occurred, all groves produced yields and incurred costs dependent on the tree age, and the tree age advanced another year. If a moderate freeze occurred, a) High Tunnel groves produced a yield based on tree age and advanced one year in tree age, b) Unprotected and Micro-jet produced no yields in the fall, regardless of tree age, and c) tree age for all groves advanced another year. If a severe freeze occurs, a) Unprotected groves were assumed to die and were re-planted in late spring, b) Micro-jet groves lived and advanced one year in tree age, produced no fruit in the fall but had yields the following year based on tree age and that year’s freeze occurrence, and c) High Tunnel groves produced a yield based on tree age and advanced one year in tree age.

Table 1. Effect of Freeze Event on Yield of Simulated Satsuma Grove

Freeze Event	Satsuma Grove		
	Unprotected	Micro-jet	High Tunnel
No Freeze	no effect	no effect	no effect
Moderate	lose crop	lose crop	no effect
Severe	lose tree	lose crop	no effect

3) Direct and variable input costs of materials and labor are a factor of tree age and fruit yield; tree age and/or yield were affected by freeze event for unprotected and micro-sprinkler protected groves (Appendix Tables A1 and A2). No limit was placed on the number of times a grove was replanted and incurred re-establishment costs again following a severe freeze in the simulations.

An enterprise budget was used as the basis for the model with the random values being freeze event and tree yield. The key output variables were total revenue, returns above variable costs, and net returns to management. The budget for each hypothetical grove was simulated for 1,000 iterations using Excel 2003© and the add-in program Simetar©. The simulations were run at the standard values for fruit price, yield ratio, and high tunnel cost, which were $.50 per pound, 2.0, and $4,500 per tunnel, respectively. Additional scenarios were also simulated for fruit prices ranging from $.25 to $1.00 per pound, for yield ratios ranging from 1.5 to 3.0, for high tunnel fixed costs ranging from $1,500 to $5,500 per tunnel, and for high tunnel variable costs ranging from 50 to 125-percent of the standard. The yield ratio and tunnel cost scenarios had no effect on the returns for the unprotected and the micro-sprinkler protected trees and were used for sensitivity analysis of the high tunnel production system.

2.4 Simulation Results and Discussion

2.4.1 Simulations with Standard Values

Results for the baseline simulations using standard parameters are presented in Table 2. This table details the values used as the key parameters, and summarizes the costs, revenues, and returns that were discounted at 6-percent and totaled over the 20-year simulation period for each production scenario. Interim values, totaled at 5-year increments, for the Income Above Variable Costs and Net Return to Management variables are also presented in this table. The interim values give an indication of how quickly each strategy produced positive net returns to management. Descriptive statistics for the 20-year key output variables are presented in Table 3.

Average total fruit production for the 20-year period was 7,080,202 pounds for the High Tunnel grove. The High Tunnel strategy was modeled to give total protection from freeze losses for both the trees and fruit and therefore the yield represents the maximum possible in the absence of freezes. In comparison, the average production from the Micro-jet and the Unprotected groves were reduced by 24.7-percent and 53.3-percent, respectively. Simulations were standardized through the yield-ratio to equate the groves on an equivalent yield basis. In the absence of freezes, all groves would be expected to have the same total production. Fruit yields for the Unprotected and Micro-jet groves would change only with variation in freeze probability or changes in the tree yield assumptions.

Table 2. Twenty-year Discounted Costs and Returns for 10-Acre Satsuma Grove in South Alabama with Different Freeze Protection Methods.

KEY PARAMETERS:					
Freeze Probability:	Severe: 0.11	Moderate: 0.14			
Discount Rate	0.06	GRKS Yield Distribution			
Conventional Trees/Acre	116	Min, Mean, Max			
High-Density Trees/Tunnel	30	.75, 1.0, 1.25			
	Standard	Scenarios - Evaluated			
Price ($/lb)	0.50	0.25	0.50	0.75	1.00
Yield Ratio (Conven./High Density)	2.0	1.5	2.0	2.5	3.0
Tunnel Fixed Cost ($/Tunnel)	4,500	2,500	3,500	4,500	5,500
Tunnel Variable Cost ($/Tunnel)	1.00	0.50	0.75	1.00	1.25
		Yield Ratio			
	Standard	1.5	2.0	2.5	3.0
Tunnels/Conventional Acre	7.7	5.8	7.7	9.7	11.6
High-Density Tree/Acer Equiv	232	174	232	290	348

Time Period	Conventional + Unprotected	Conventional + Micro-jet	High Tunnel High Density
	Discounted Income Above Variable Costs:		
5 Year	16,790	29,132	-27,226
10 Year	164,010	283,297	257,435
15 Year	288,933	507,909	517,597
20 Year	383,018	676,173	712,019
	Discounted Net Return to Management:		
5 Year	-18,591	-28,057	-225,651
10 Year	110,369	194,765	-48,318
15 Year	221,672	395,955	131,642
20 Year	305,575	546,718	266,132

		Unit	$/Unit	Unprotected	Micro-jet	High Tunnel
GROSS RECEIPTS	Yield/10 Ac or Ac equiv.	lb		3,305,089	5,332,031	7,080,202
	Discounted Revenue	ac/ac equiv		$828,601	$1,317,314	$1,748,953
VARIABLE/DIRECT COSTS						
	Pest/Disease/Weed Control	ac/ac equiv.	variable	43,777	55,044	40,064
	All other material inputs	ac/ac equiv.	variable	26,495	30,507	30,507
	Other Labor	ac/ac equiv.	variable	52,988	57,262	57,262
	Pruning Labor	hr	9.60	5,431	6,261	12,523
	Specific System Maintenance	ac/ac equiv.	variable	0	3,303	238,072
	Harvest Labor & Materials	bushel	3.50	145,108	230,541	306,067
	Other Harvest/Pack Costs	ac/ac equiv.	variable	151,689	229,021	305,362
	Interest on Operating Capital	ac/ac equiv.	variable	20,211	29,067	47,018
ESTABLISHMENT COSTS						
	Land Prep/Plants/Labor	ac/ac equiv.	variable	34,997	13,852	26,236
FIXED COSTS						
	Equipment & Irrigation	ac/ ac equiv		42,450	43,583	43,583
	Freeze Protection or Tunnel	ac/ ac equiv	variable	0	72,020	376,068

Table 3. Twenty-Year Key Output Variables[a] from Simulations using Standard Parameters[b]

	Unprotected	Micro-jet	High Tunnel
Total Revenues	$828,601	$1,317,314	$1,748,953
Standard Deviation	360,827	190,916	55,237
Coefficient of Variation	44	14	3
Income Above Variable Costs	$383,018	$676,173	$712,019
Standard Deviation	222,405	125,547	45,103
Coefficient of Variation	58	19	6
Net Return to Management	$305,575	$546,718	$266,132
Standard Deviation	232,630	125,547	45,103
Coefficient of Variation	76	23	17

[a] Values are discounted at 6%.

[b] Yield ratio = 2.0, high tunnel cost = $4,500/tunnel, and market price = $.50/lb.

Producers in the Gulf Coast area have been able to sell all of the fruit they produced at prices ranging from $.30 to $.80 per pound. Based on conversations with industry specialists, the market price of $.50 was used as the average expected price and the standard for the simulations. At the market price of $.50 per pound, all production methods modeled had positive net returns after 20 years. Using either freeze protection method reduced the variability of net returns, but at this market price, mean returns for the Micro-jet grove were superior to the other two methods. The Unprotected grove produced 38-percent less fruit than the Micro-jet grove due to severe-freeze-induced tree loss, and the subsequent production lag following replanting. The Micro-jet grove lost fruit, but not trees, after severe freezes and returned to normal production the following year. Even though the High Tunnel grove had greater total fruit production than the Micro-jet grove, at the standard market price, yield ratio, and tunnel cost, the 20-year net returns to management are 51-percent less. The relatively higher initial investment and the higher annual maintenance cost for the high tunnels are the primary costs contributing to reduced net returns for the High Tunnel grove in comparison with the Micro-jet grove.

2.4.2 Stochastic Dominance

The cumulative density functions (CDF) for the three standard simulations are illustrated in Figures 1 and 2, for market prices of $.50/lb and $1.00/lb, respectively. Under first-degree stochastic dominance, plan A would dominate plan B if $F_A(x) \leq F_B(x)$ for all levels of x (Harwood, et al., 1999). There is no clear dominance of one strategy

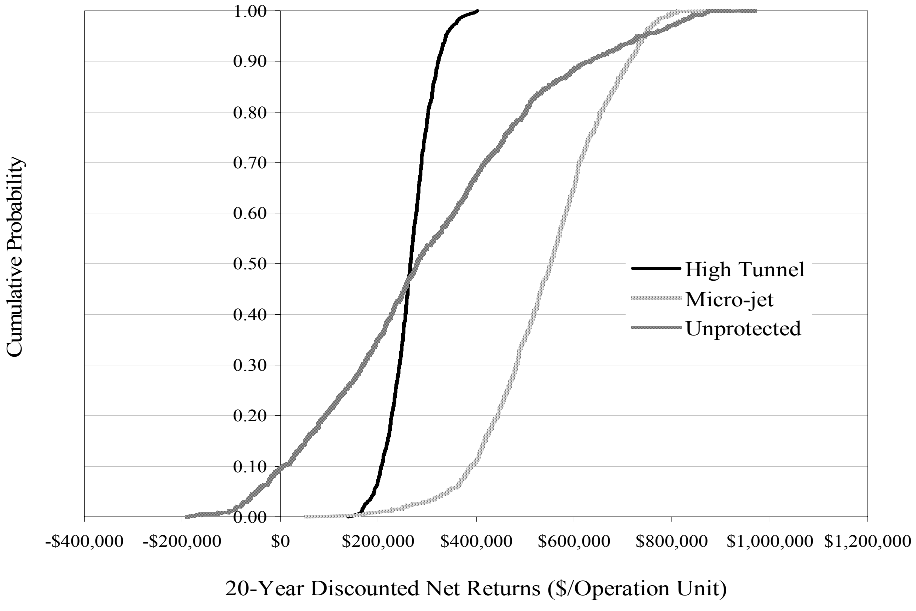

Figure 1. Cumulative Distributions of 20-Year Discounted Net Returns to Management for Three Satsuma Production Strategies at Market Price = $.50 per Pound

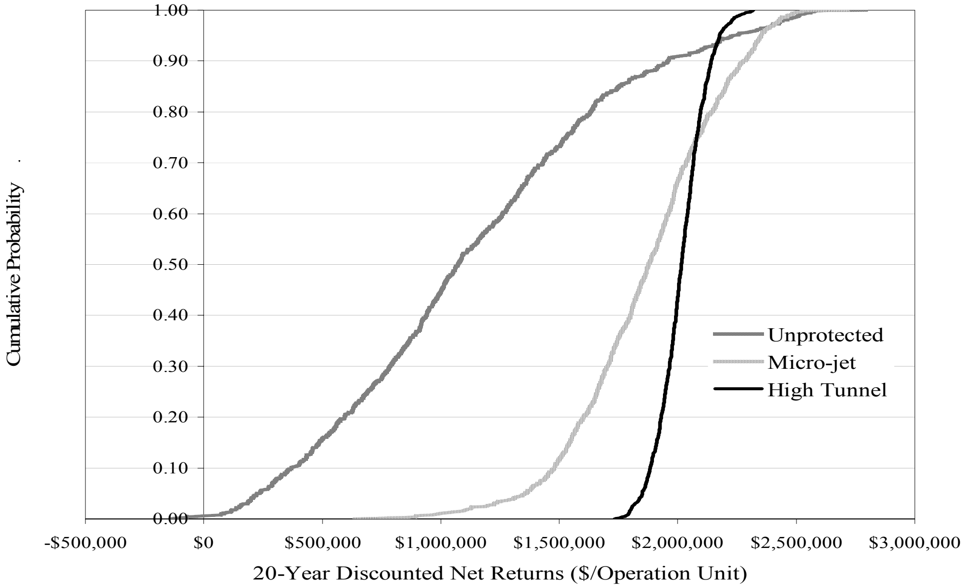

Figure 2. Cumulative Distributions of 20-Year Discounted Net Returns to Management For Three Satsuma Production Strategies at Market Price = $1.00 per Pound

over the other in either price scenario because each CDF crosses another at some point. However, at $.50/lb market price, the Micro-jet strategy exhibits first degree stochastic dominance over the other two strategies except in the upper and lower tails of the distribution of returns. To rank the strategies, second-degree stochastic dominance procedures must be used and preference between the strategies would depend upon the decision maker's utility function and risk aversion preference.

Stochastic Dominance with Respect to a Function (SDRF) in Simetar© is a mathematically rigorous method of using the complete empirical distribution to rank scenarios with different risk strategies (Richardson, 2004). It relies on theory for the measurement of risk aversion developed by Pratt (1964) where decision makers have an expected utility function for money, u(x), that is increasing and twice differentiable. The absolute risk aversion coefficient (ARAC) is defined as $r(x) = -u''(x)/u'(x)$. While Pratt limits the coefficient to describe risk adverse individuals, where $u'(x) > 0$ and $u''(x) < 0$, the Simetar© program follows Meyer (1977) and allows for a grouping of decision makers into risk preference groups based on similar ARACs:

> Let $U(r_1(x), r_2(x))$ represent decision makers with preferences represented by $r(x)$ over the range $r_1(x) \leq r(x) \leq r_2(x)$ for all x.

Using the above assumptions and distributions F and G bounded over the interval of 0 to 1, two risky alternatives, F(x) and G(x), with utility function u(x) are compared. Over the probability range of zero to one, F(x) is preferred to G(x) when:

$$(1) \qquad \int_0^1 u(x)\, d\, F(x) \;\geq\; \int_0^1 u(x)\, d\, G(x).$$

Rearrangement of equation (1) yields:

$$(2) \qquad \int_0^1 [G(x) - F(x)]\, u'(x)\, dx \;\geq\; 0.$$

The SDRF program requires an assumption on the form of the utility function. Following Featherstone and Moss (1990), a negative exponential utility function was assumed such that:

$$(3) \qquad U\,[W(x)] = -\exp\,[-\theta W(x)],$$

where wealth, W, is a function of net return, x, and θ is the Pratt absolute risk aversion coefficient. The negative exponential utility function assumes constant absolute risk aversion and increasing relative risk aversion.

The stochastic dominance function also utilizes the utility function to calculate certainty equivalents (CE) coefficients to rank alternative strategies. The CE value is the net return required so that a decision maker with a given ARAC and utility function would be indifferent between the investment and a no-risk investment. To calculate certainty equivalents from the negative exponential utility function, an assumption is also made that returns are distributed multivariate normal such that $W(x) \sim N[\mu(x), \sigma^2(x)]$. Given these assumptions, Featherstone and Moss (1990) detail the derivation of the certainty equivalent formula from equation (3) by setting the inverse utility function to be equal to the expected utility. The resulting certainty equivalent formula is:

$$(4) \qquad CE = W^*(x) = \mu(x) - \theta/2\ \sigma^2(x),$$

where $W^*(x)$ is the certainty equivalent, $\mu(x)$ is the expected mean net return, $\sigma^2(x)$ is the variance, and θ is the Pratt ARAC.

The SDRF program was run for the simulation distributions using an ARAC range of $-0.1 \leq r(x) \geq +0.1$ and the negative exponential utility function for three market price scenarios. The certainty equivalents and rankings of the different production strategies are presented in Table 4. The ranking preference, based on CEs changed as the absolute risk aversion coefficient changed from negative (risk loving) to positive (risk averse). With ARAC = 0 (risk neutral), the CE is equal to the mean of the net return to management with no consideration of the variance of the distribution. For a risk averse decision maker with the assumed utility function, the High Tunnel strategy is preferred in all market price scenarios; the lower variance in distribution of net returns to management for the High Tunnel strategy is a significant factor in this result at price levels of \$.50 and \$.75/lb.

2.4.3 Equivalent Prices

The 20-year discounted net returns for all freeze protection strategies has a linear response to market price, as illustrated in Figure 3. Equivalent prices between the strategies, calculated from the response slopes, are \$.253 between Unprotected and Micro-jet, \$.521 between Unprotected and High Tunnel, and \$.827 between Micro-jet and High Tunnel. The equivalent prices are market prices where the mean 20-year net returns to management are equal between the two strategies being compared. The large increase in the equivalent prices when alternative strategies are compared to the High Tunnel indicates that the expense of growing trees in high tunnels can only be justified if market prices are expected to exceed these equivalent prices, given the assumptions in the simulation and risk neutral preferences.

Table 4. Effect of Market Price and Absolute Risk Aversion Coefficient on Certainty Equivalents and Ranking for Three Satsuma Production Strategies with Negative Exponential Utility Function

	Absolute Risk Aversion Coefficient[a]					
	-0.1		0		0.1	
	CE[b]	Rank	CE[b]	Rank	CE[b]	Rank
Price = \$.50/lb						
Unprotected	969,498	1	305,455	2	-189,748	3
Micro-jet	894,018	2	546,850	1	53,865	2
High Tunnel	402,665	3	266,192	3	138,863	1
Price =\$.75/lb						
Unprotected	1,881,971	1	719,756	3	-162,619	3
Micro-jet	1,806,491	2	1,205,507	1	344,755	2
High Tunnel	1,360,695	3	1,140,669	2	935,385	1
Price = \$1.00/lb						
Unprotected	2,794,444	1	1,134,057	3	-135,490	3
Micro-jet	2,718,963	2	1,864,163	2	635,644	2
High Tunnel	2,318,724	3	2,015,145	1	1,731,908	1

[a] Negative ARAC = Risk loving, 0 = Risk neutral, Positive ARAC = Risk averse.

[b] CE = Certainty Equivalent.

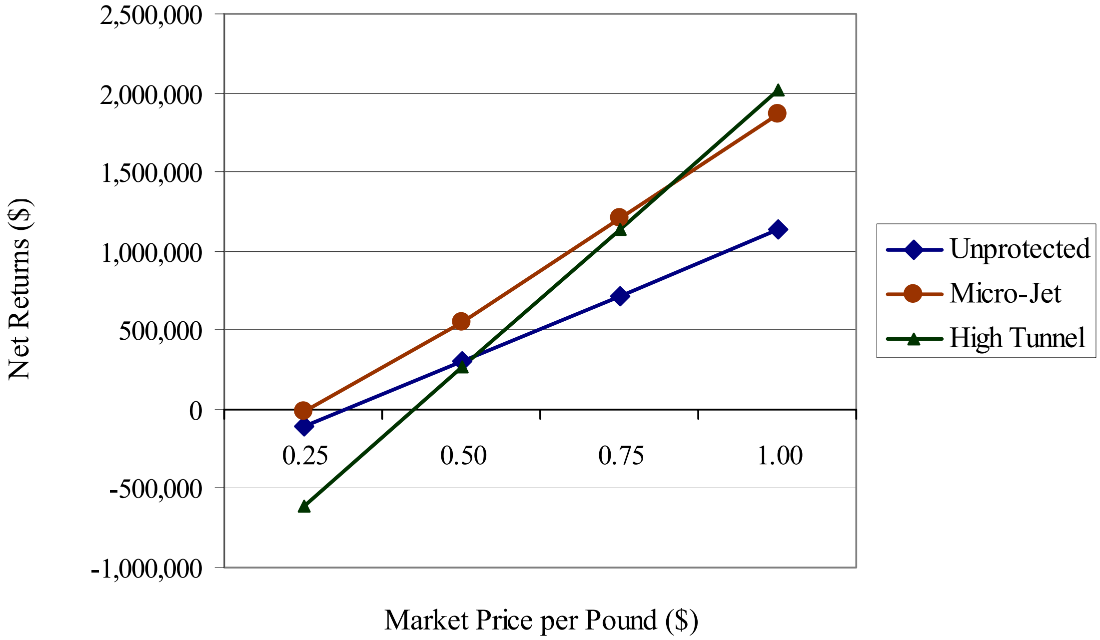

Figure 3. Twenty-Year Discounted Net Returns to Management for Satsuma at Different Different Market Prices, Fairhope, Alabama

2.4.4 High Tunnel Cost Analysis

Total elimination of freeze risk for Satsuma production in the Gulf Coast region of Alabama would increase production efficiency and potentially benefit both producers and consumers. There is currently no oversupply of production and an opportunity for expanding sales exists. Under these conditions, a negative market price response would not be expected with increased production. However, the use of high tunnels to eliminate the risk of crop loss due to freeze may require higher average market prices than currently exist or lower production costs. Production costs for the High Tunnel strategy are affected by the yield ratio used to equate the high density planting to the conventional planting (yield from tree on standard rootstock in relation to yield from tree on dwarf rootstock), the fixed construction costs, and the annual maintenance costs. Simulations were run with scenarios that varied these input values to evaluate their effect on net return.

The simulation results from varying the high tunnel fixed costs and the yield ratio on 20-year net returns across a range of market prices are presented in Table 5. The effect of varying the initial tunnel construction cost on 20-year discounted net returns is a simple algebraic equation given that the discount rate and the amortization rate assumptions used in the simulations are both 6-percent. A one-dollar decrease in tunnel cost will result in a net return increase of one dollar per tunnel with the number of tunnels varying due to the yield ratio.

Yield ratio had an inverse effect on net returns. Yield ratio is the ratio of the yield of a tree on conventional ‘Rubidoux’ rootstock to the yield of a tree on the dwarfing rootstock ‘Flying Dragon’. As the yield ratio increased, there was a greater negative effect on the net returns due to the increased number of tunnels needed to equal conventional production. Each increase of .5 in the yield ratio resulted in approximately a 10-percent increase in the breakeven price for all high tunnel costs. Market price effects, for the different strategies, reflected changes in total fruit production and net returns exhibited a linear response to price. Each 25-cent increase in market price increased net returns by $414,301 for the Unprotected grove, $658,657 for the Micro-jet grove and $874,477 for the High Tunnel grove over the 20 year life of the project.

Table 5. Simulated Discounted[a] 20-Year Net Return to Management at Different Price Levels for Satsuma with Different Freeze Protection Methods - Fairhope, Alabama

			High Tunnel Cost[b]				
			$1,500	$2,500	$3,500	$4,500	$5,500
Price/lb	Unprotected	Micro-Jet			Ratio[c] = 1.5		
0.25	-108,845	-11,807	-267,832	-325,827	-383,827	-441,809	-499,832
0.50	305,456	546,850	610,451	552,451	494,451	436,451	378,451
0.75	719,757	1,205,507	1,488,711	1,430,711	1,372,711	1,314,711	1,256,711
1.00	1,134,057	1,864,164	2,366,971	2,308,971	2,250,971	2,192,971	2,134,971
Price Intercept[d]	0.316	0.292	0.326	0.343	0.359	0.376	0.392
					Ratio[c] = 2.0		
0.25			-377,308	-454,303	-531,303	-608,285	-685,303
0.50			497,192	420,192	343,192	266,192	189,192
0.75			1,371,669	1,294,669	1,217,669	1,140,669	1,063,669
1.00			2,246,145	2,169,145	2,092,145	2,015,145	1,938,145
Price Intercept[d]			0.358	0.380	0.402	0.424	0.446
					Ratio[c] = 2.5		
0.25			-485,437	-582,418	-679,437	-776,437	-873,437
0.50			395,872	298,872	201,872	104,872	7,872
0.75			1,277,163	1,180,163	1,083,163	986,163	889,163
1.00			2,158,453	2,061,453	1,964,453	1,867,453	1,770,453
Price Intercept[d]			0.388	0.415	0.443	0.470	0.498
					Ratio[c] = 3.0		
0.25			-594,433	-710,433	-826,433	-942,433	-1,058,433
0.50			283,849	167,849	51,849	-64,151	-180,151
0.75			1,162,113	1,046,113	930,113	814,113	698,113
1.00			2,040,377	1,924,377	1,808,377	1,692,377	1,576,377
Price Intercept[d]			0.419	0.452	0.485	0.518	0.551

[a] Discount rate is 6.0%. [b] Dollar cost per tunnel.

[c] Yield ratio for Conventional:High Density (High Tunnel) plantings. [d] Break-even price/lb of fruit produced.

An evaluation of the equivalent prices restates the relationship between the High Tunnel strategy and the other two strategies in terms of fruit market price (Table 6). Equivalent prices are the market price where the mean 20-year net returns are equal between the two strategies being compared and were calculated from the price response regression lines. Average market prices above the equivalent price indicate that net returns are higher for the strategy that has the higher yield. With a yield ratio of 2.0 or less, the High Tunnel strategy would return more than the Unprotected strategy at market prices in the range of $.50 per pound, however, they would not return more than the Micro-jet strategy were equivalent prices are generally in excess of $.50 per pound. An advantage to using high tunnel technology would be the expectation of a crop in the event of either a severe or a moderate freeze; a risk adverse decision maker may consider the use of this technology for reasons other than achieving the greatest average net return. Horticultural research focusing on pruning methods, tree nutrition, and other factors affecting fruit yield may potentially impact the cost effectiveness of the high density planting.

Table 6. Equilavent Prices between Freeze Protection Technologies with Varying Yield Ratios and High Tunnel Fixed Cost

	Unprotected				Micro-Jet			
Unprotected	1	1	1	1	0.253	0.253	0.253	0.253
Micro-Jet	0.253	0.253	0.253	0.253	1	1	1	1
High Tunnel	Yield Ratio				Yield Ratio			
Fixed Cost:	1.50	2.00	2.50	3.00	1.50	2.00	2.50	3.00
HT - $1,500	0.335	0.396	0.454	0.511	0.428	0.558	0.680	0.801
HT - $2,500	0.367	0.437	0.506	0.573	0.494	0.648	0.791	0.933
HT - $3,500	0.398	0.479	0.558	0.636	0.561	0.737	0.901	1.066
HT - $4,500	0.429	0.521	0.611	0.698	0.627	0.827	1.012	1.198
HT - $5,500	0.460	0.563	0.663	0.761	0.693	0.916	1.123	1.330

Simulations that varied the annual maintenance costs for the High Tunnel strategy were also run (Table 7). A one-percent decrease in variable costs was found to increase 20-year discounted net returns by $2,492 at the standard yield ratio of 2.0. In comparison, a one-percent decrease in fixed construction cost resulted in an increase of $3,465 for 20-year discounted net returns. These changes in net return were static and were not affected by market price of fruit. Reduction in either the initial construction costs or the annual variable costs were assumed to have no effect on the performance of the high tunnels. Cost reductions may be achieved through any number of ways including increased labor efficiency and volume discount purchases of materials. The effects of changing the variable and fixed costs on the break-even price for the high tunnel grove, at the standard yield ratio of 2.0, are also presented in Table 7.

Table 7. Simulated Discounted[a] 20-Year Net Return to Management at Different Price Levels for Satsuma with Changes in High Tunnel Variable Costs - Fairhope, Alabama

			High Tunnel Cost[b]				
			$1,500	$2,500	$3,500	$4,500	$5,500
Price/lb	Unprotected	Micro-Jet	Variable Cost = .50*Standard				
0.25	-108,845	-11,807	-252,689	-329,689	-406,689	-483,712	-560,708
0.50	305,456	546,850	621,787	544,787	467,787	390,787	313,787
0.75	719,757	1,205,507	1,496,264	1,419,264	1,342,264	1,265,264	1,188,264
1.00	1,134,057	1,864,164	2,370,741	2,293,741	2,216,741	2,139,741	2,062,741
Price Intercept[c]	0.316	0.292	0.322	0.344	0.366	0.388	0.410
			Variable Cost = .75 * Standard				
0.25			-315,005	-392,005	-469,010	-546,010	-623,005
0.50			559,490	482,490	405,490	328,490	251,490
0.75			1,433,966	1,356,966	1,279,966	1,202,966	1,125,966
1.00			2,308,443	2,231,443	2,154,443	2,077,443	2,000,443
Price Intercept[c]			0.340	0.362	0.384	0.406	0.428
			Variable Cost = Standard				
0.25			-377,303	-454,303	-531,303	-608,285	-685,285
0.50			497,192	420,192	343,192	266,192	189,192
0.75			1,371,669	1,294,669	1,217,669	1,140,669	1,063,669
1.00			2,246,145	2,169,145	2,092,145	2,015,145	1,938,145
Price Intercept[c]			0.358	0.380	0.402	0.424	0.446
			Variable Cost = 1.25 * Standard				
0.25			-439,605	-516,601	-593,601	-670,601	-747,601
0.50			434,894	357,894	280,894	203,894	126,894
0.75			1,309,371	1,232,371	1,155,371	1,078,371	1,001,371
1.00			2,183,848	2,106,848	2,029,848	1,952,848	1,875,848
Price Intercept[c]			0.376	0.400	0.420	0.441	0.464

[a] Discount rate is 6.0-percent. [b] Dollar cost per tunnel. [c] Dollar cost per tunnel.

Note: The Yield Ratio for conventional:high density (High Tunnel) plantings is 2.0.

Break-even prices at the 2.0 yield ratio range from \$.322 to \$.464 per pound with the input assumptions used in the simulations that varied high tunnel variable and fixed costs. Break-even prices across all yield ratios ranged from a low of \$.326 to a high of \$.551 per pound when only fixed costs were varied (Table 5). These prices indicate that it would economically feasible to produce Satsuma mandarins with high tunnel technology for freeze protection when market prices are above \$.45 per pound at the standard yield ratio 2.0, and above \$.55/lb at the 3.0 yield ratio.

An important advantage of the high tunnels was the reduction in the variance of revenues and net return to management over the 20-year period (Table 3). However, because of the significant investment and maintenance costs for the high tunnels, other freeze protection methods may have greater average returns to management in the Gulf Coast area. The high tunnel economic evaluation developed for the Gulf Coast area may be preferred in other areas that have higher freeze risk as long as the tunnels offer sufficient protection from the minimum temperatures for the area of interest. It may be necessary to add supplemental heat to adequately protect trees with high tunnels in many areas; the analysis in this study will be relevant as long as the fixed and variable costs for the tunnel and additional heat source are maintained within the ranges evaluated.

2.5 Conclusions

Three Satsuma mandarin groves with different freeze protection strategies were evaluated in this study through the simulation of their respective enterprise budgets over a 20-year investment horizon. The grove with no freeze protection (Unprotected) and the grove with micro-sprinkler freeze protection (Micro-jet) were modeled as 10-acre enterprises with 116 trees to the acre. The higher-density planting with high tunnel freeze protection (High Tunnel) was equated to the other groves on a yield basis through a yield ratio which is the ratio of the expected yield from an 'Owari' Satsuma on 'Rubidoux' rootstock to the expected yield of 'Owari' Satsuma on the dwarfing rootstock, 'Flying Dragon'. With the standard yield ratio of 2.0, 77 high tunnels were needed to equal the expected production from the 10-acre enterprises. The groves were simulated using standard values of $4,500 high tunnel construction cost, a 2.0 yield ratio, and $.50 per pound wholesale market price for fruit. Total revenues, return above variable costs, and net return to management were key output variables that were discounted at 6 percent over the 20-year period.

Using the standard input variables, all groves had positive discounted net returns to management after 20 years. At the $.50 per pound market price, the mean returns were highest for the Micro-jet strategy, but the returns for the High Tunnel strategy had the lowest variance. Preference between the strategies may depend upon the decision makers utility function and risk preferences.

All strategies exhibited a linear response to market price. Changes in the market price resulted in the greatest change in 20-year net returns for the High Tunnel strategy, followed by the Micro-jet, and then the Unprotected. The ranking of net-return response to market price was due to the total fruit production for each strategy over the 20-year period. The use of high tunnels eliminated production loss due to tree or fruit injury in these simulations. The lowest total yields were attributed to the Unprotected strategy, which was subject to tree and/or fruit loss depending upon the freeze severity each year.

Total elimination of freeze risk in the Gulf Coast region of Alabama with the use of high tunnels necessitates a significant investment in high tunnel initial construction and annual maintenance costs. Maintaining, or improving, a 2.0 yield ratio between conventional plantings on 'Rubidoux' rootstock and high-density plantings on 'Flying Dragon' rootstock is a subject open for horticultural study. Yield ratio determines the number of tunnels needed to equal one acre of conventionally spaced production. As the yield ratio increases, more tunnels are needed to equal the potential yield of the trees with conventional plant spacing and net returns become more sensitive to the effect of tunnel costs.

Sensitivity analysis varying the fixed and variable costs for the High Tunnel strategy showed that a one-percent decrease in high tunnel fixed cost resulted in a $3,465 increase in 20-year discounted net returns and a one-percent decrease in variable maintenance costs resulted in a lesser decrease of $2,492. Break-even prices across all yield ratios, fixed costs, and variable cost combinations ranged from a low of $.300 per pound to a high of $.551 per pound. The break-even prices indicate the market price at which it is economically feasible to produce Satsuma mandarins with high tunnel freeze protection under the different given assumptions.

Freeze protection with high tunnels requires significant investment and maintenance costs for the high tunnels, and other freeze protection methods may have greater returns to management in the Gulf Coast area. The high tunnel economic evaluation developed for the Gulf Coast area may be used in any area with greater freeze risk as long as the tunnels offer sufficient protection from the minimum temperatures for the area of interest. Additional simulations based on this platform can be used to determine the freeze probability conditions under which High Tunnel technology would be preferred to Micro-jet technology.

IV. EFFECT OF LOCAL VARIATION IN FREEZE PROBABILITY ON NET RETURNS FROM THREE PROTECTION TECHNOLOGIES

3.1 Introduction

Reduction of risk in agriculture is a subject of much interest for producers and researchers alike and there is a large body of literature devoted to the subject. Risk, in its simplest term, refers to the possibility of experiencing a loss with a given probability of occurrence. In order to achieve effective risk reduction, either the severity of the loss or its probability must be reduced to the extent that the outcome is improved. Practices that reduce the severity of loss are termed "loss reduction" or "self insurance", while practices that reduce the probability of loss are termed "loss prevention" or "self protection" (Briys and Schlesinger, 1990). It is not always possible, however, to know the distribution of a risk variable due to its random occurrence and this introduces uncertainty into the decision process (Knight, 1921).

In Chapter 2, an economic evaluation of risk reduction methods for a Satsuma mandarin grove in the Fairhope, AL area, was presented. The methods evaluated were micro-jet sprinkler irrigation to prevent the loss of trees due to freeze, and high tunnels to prevent the loss of both trees and fruit due to freeze. Each of these methods is a form of self-insurance; they do not prevent the freeze event from occurring, but reduce the deleterious effects of the freeze event on profitability of the grove. Investment in self-insurance has been shown to increase with an increase in the decision maker's risk aversion (Hiebert, 1989, Dionne and Eeckhoudt, 1985, Ehrlich and Becker, 1972). With consideration of the level of risk aversion, both the expected net return and the associated distribution of returns are important to the decision maker. An assumption of risk neutral preference, however, simplifies the comparison of different self-insurance methods to an evaluation of the expected net return. A risk neutral individual would prefer the strategy that yields the highest expected net return.

Satsuma mandarins require mild winters and cool autumn temperatures in allow for tree survival and optimum fruit quality (Ebel et al., 2004). In the United States these conditions are found in the northern Gulf Coast region states, and in certain areas of Arizona and California. In the Gulf Coast region, minimum winter temperatures may reach levels that cause tree injury. The evaluations in Chapter 2 were conducted using the probability of severe and moderate freeze events developed from weather data and observations of tree injury over a 56-year period for the Fairhope, AL area. Severe freeze was classified as one that caused extensive tree injury or tree death, and a moderate freeze was classified as one that caused extensive leaf injury and some stem dieback to the extent that the next season's fruit crop was destroyed. While historical data is not an ideal predictor of future events, it is the best indication of the expected long-term freeze probability available in the absence of more accurate weather prediction models.

The occurrence of weather events in any given location are considered acts of nature that cannot be directly influenced by the actions of a producer. However, an expectation of weather events, or probability of a weather event occurring, develops for different locations based on experience. A potential Satsuma producer in a location other than the Fairhope, AL region would be expected to face different injurious freeze probabilities. Development of cultivars that are more cold tolerant than those used in current production or possible changes in global weather patterns could also change the expectation of freeze injury probability for a given location. It is not within the scope of this paper to determine how the changes would occur, but rather what would be the effect of different probabilities of severe or moderate freeze injury on the outcome of the simulation models. This information would be useful for decision makers facing uncertainty in future weather events.

Net returns for Satsuma production under different freeze protection strategies would be expected to vary due to the occurrence of freeze events. This information would be useful to a decision maker facing uncertainty in future weather events or who has an expectation of freeze probabilities different from those used for the Fairhope, AL area. The objective of this study was to determine the effects of varying freeze probabilities on discounted net returns for hypothetical Satsuma groves that use different approaches to freeze protection. In the rest of this chapter, a review of the literature will be followed by a description of the methodology used, discussion of the results, and concluding remarks.

3.2 Review of Literature

3.2.1 Weather Data and Satsuma Cold Acclimation

Long-term weather data, from 1948 to 2004, was matched to historical reports and research records of freeze injury on Satsuma in the Fairhope region to determine the probability of freeze occurrence and severity in this area (Ebel, et al., 2005). During this period, no more than two freeze events occurred in any given winter season (December through March) and the duration was less than three days for all occurrences except one. The effect of critical temperatures on Satsuma plants will be dependent upon the plant's level of acclimation to cold prior to the freeze event. The air temperature during the 500 hours (≈ 3 weeks) preceding the freeze event have been determined to be the most important factor affecting cold acclimation (Yelenosky,1985, 1991, 1996). Trees were found to acclimate to cold when the air temperatures were ≤ 50 ^{o}F (10 ^{o}C). Ebel, et al. (2005) developed a model to determine the expected sensitivity of Satsuma to cold injury that incorporated the level of tree cold acclimation prior to exposure to potentially injurious temperatures. Trees that were not fully acclimated experienced economically important injury at temperatures of 22 ^{o}F (-5.5 ^{o}C) and tree death at temperatures below 14 ^{o}F (-10 ^{o}C). When trees are fully acclimated they could withstand temperatures down to 18 ^{o}F (-7.7 ^{o}C) before experiencing economically important injury and tree death did not occur until temperatures reach 12 ^{o}F (-11.0 ^{o}C).

Concerns about possible climate change, either from long-term natural weather patterns or human induced weather changes, are widespread; there are many interdisciplinary studies being conducted and models being developed to evaluate the impact of climate change (Goulder and Pizer, 2006; Reilly, et al., 2003; US Global Change Research Program, 2006). Easterling et al., (1999) reviewed the literature on recorded freeze data from 1766 though the 1990's and the occurrence of freeze injury to citrus in Florida. The studies that were reviewed found an association between freeze injury and the strong positive mode of the Pacific-North American (PNA) circulation pattern and no association with the El Niño – Southern Oscillation (ENSO). Katz, Parlange, and Tebaldi (2003) evaluated the relationship of nine atmosphere-ocean circulation indices with min/max temperature and precipitation time-series data (1959-1996) for the southeastern United States. They established an association of higher minimum and maximum winter temperatures and higher probability of precipitation when the Bermuda High was farther east than average. Long-term and short-term weather cycles appear to occur but are not yet predictable (US Global Change Research Group, 2006) and therefore are ignored in the current study. Nevertheless, if changes in long-term weather patterns result in warming trends, an increase in the minimum temperature that occurs in an area, could also decrease tree cold acclimation and result in more frequent, though less severe, tree injury.

3.2.2 Satsuma Production Areas

Satsuma mandarin is one of the most cold-hardy of the commercially grown citrus; however minimum winter temperatures in the Gulf Coast region of the US may reach levels that cause injury to trees. Moving Satsuma production to areas with lower probability of freeze occurrence may have adverse effects on fruit quality. High air temperature during the final fruit maturation period of October through December promotes poor peel color development and may accelerate the decrease in acidity to the extent that flavor is less than ideal (Ebel et al., 2004). These quality features benefit from cool temperatures during the final fruit maturation. Producing Satsuma in areas that are further north could increase the probability of either severe or moderate freeze injury and require higher levels of freeze protection. The USDA Plant Hardiness Zone map may be useful to a potential producer to identify suitable production areas.

Fairhope, AL is located in USDA Plant Hardiness Zone 8b, with average annual minimum temperature range of 15 to 20 ^{o}F (-9.4 to -6.7 ^{o}C). Satsuma are expected to be hardy to (-10 ^{o}C) and should thrive in Zone 8b. Over the 56 year period, 1948-2004, there have been 11 years when the Gulf Coast Research Center at Fairhope, AL recorded minimum temperatures below this average with the absolute minimum recorded during this period being 5.2 ^{o}F (-14.9 ^{o}C). The hardiness zone map was published in 1960 and revised in 1965; it is drawn on average annual minimum temperatures, which, necessitates that there are occurrences of temperatures below this range. The weather data collected by the Gulf Coast Research Center indicates that annual minimum temperatures were below the Hardiness Zone Map an average of 20-percent of the time from 1948-2004. The USDA Plant Hardiness Zone map may give an indication of areas that are suitable for Satsuma production, but more detailed minimum temperature information is required to develop an appropriate freeze probability factor for a given area.

3.3 Methodology

3.3.1 The Simulation Model

The models developed in Chapter 2 for Unprotected, Micro-jet, and High Tunnel groves were used for simulations with variations in freeze probabilities. Simetar©, an Excel add-in program, was used with Excel 2003 to simulate the performance of each grove over a 20-year period for 1,000 iterations. The primary output variable of interest was the accumulated discounted net returns to management:

$$(1) \qquad NR_d = \Sigma\ [\ (PY_j(f(\theta),t) - C_j(t) - VC_j\ (y))\ /\ (1 + r)^j\ ]$$

where NR_d = total discounted net returns over the 20-year period; j = the simulation year; P = market price per pound; Y = fruit yield as a function of tree age, t, and freeze event, f, that occurs with probability θ; $C_j(t)$ = fixed and direct costs in the jth year as a function of tree age; VC_j = variable costs as a function of yield in the jth year; and r = the discount rate. The 20-year net return variable is linear in price.

The simulations were conducted over a range of prices in order to calculate price response lines. Price response lines were used to determine break-even prices for each strategy and equivalent prices between the strategies for each simulation scenario. Break-even prices are equal to the price intercept from the price response line. Equivalent prices are the market price where the price response lines from two different strategies intersect:

$$(2) \qquad EP_{ab} = (PI_a - PI_b)\ /\ (S_b - S_a)$$

where subscripts a and b refer to two different production strategies; EP is the equivalent price; and PI and S are the intercept and slope, respectively, of the applicable price response line.

3.3.2 Model Variables

The basic unit of study was a hypothetical 10-acre Satsuma grove with a planting density of 116 trees per acre. There were three groves modeled: 1) one grove with no freeze protection which will be referred to as “Unprotected”, 2) one with micro-jet sprinklers placed in the tree for freeze protection, referred to as “Micro-jet”, and 3) one grove protected by high tunnels, referred to as “High Tunnel”. Trees in the High Tunnel grove were grown on the dwarfing rootstock, ‘Flying Dragon’, and have a planting density of 6 feet in the row by 12 feet between rows so that each 96 x 24 foot high tunnel covers 30 trees. The dwarfing rootstock is desirable to more easily maintain tree growth within the confines of the high tunnels. The Unprotected and the Micro-jet groves on the conventional planting density were planted on ‘Rubidoux’ trifoliate orange rootstock. The groves with conventional planting density were equated to the high-density grove through equivalent yield and not through equivalent land area. Based on Japanese research (Takahara et al., 2001; Noda et al., 2001; Yonemoto et al., 2005), an assumption was made that it takes two trees on ‘Flying Dragon’ rootstock to produce the same yield as one tree on conventional ‘Rubidoux’ rootstock. This resulted in a 2.0 ratio between the yield of a conventionally grown tree and the high density tree on dwarfing rootstock. With a 2.0 yield ratio assumption, 7.7 high tunnels (231 trees) were needed to produce the same yield as one acre of trees on conventional rootstock and planting density. Thus, the 10-acre units for the Unprotected and the Micro-jet groves are assumed to have the equivalent yield potential of the High Tunnel grove with 77 high tunnel plantings.

The Louisiana Satsuma production budget, developed by Hinson, Boudreaux, and Vaughn (2006), was used as the basis of the simulation model. It was assumed that production expenses for Louisiana producers would be similar for producers in other areas of the Gulf Coast region of the United States. Irrigation was not included in the Louisiana budget but was added to each of the simulated models, including the Micro-jet grove. The freeze protection system modeled for the Micro-jet grove was too large and expensive to operate on a regular basis to be efficient for irrigation needs. The cost of establishing the groves and all variable and direct costs are realized in the year they occur. Fixed costs for machinery and irrigation are annual charges.

All costs for the freeze protection technologies were obtained from the Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama. Fixed costs associated with freeze protection for the groves are amortized at 6-percent across their respective life expectancies. Fixed costs for the micro-jet freeze protection are $6,350 per acre for a well, pump, and all below ground pipes with a 20-year life expectancy, and $185 per acre for above ground parts with a 4-year life expectancy. Fixed costs for each high tunnel are $4,500 for the frame, end-walls, doors, hardware, and two layers of 20-year ground cloth. High tunnels are assumed to have a 20-year life expectancy. There are also significant variable costs associated with materials and labor to cover the tunnels with milky-white 6-mil polyurethane each year in December and to remove the covering after the danger of freeze.

A yield curve based on tree age was developed from yield data collected on a Satsuma mandarin grove established in 1990 at the Gulf Coast Research and Extension Center in Fairhope, AL and is presented in Appendix 1.1. Trees were assumed to have no yield during the first two years of establishment and reach a mature average yield of 400 lb per tree by the ninth year after set out (Ebel, et al., 2004). A yield variation in the 25-percent range was observed among trees in the yield data collected by the Gulf Coast Research Center. The model used the GRKS distribution for Simetar© that was developed by Gray, Richardson, Klose, and Schumann (Richardson, 2004) to model a

25-percent variation from the average yield in any given year. This variation may be due to losses from sources other than freeze or it may be due to alternate bearing. An average price of $.50/lb was the assumed standard market price for all simulations.

3.3.3 Freeze Probability Matrix

There were two levels of freeze events that are economically important in the simulation models. Severe freeze was assumed to cause extensive injury or death of the tree, and moderate freeze is assumed to cause extensive leaf injury and some stem dieback to the extent that only the next season's fruit crop would be destroyed. Trees that experience moderate freeze injury recovered and produced a normal crop the following year. Satsuma mandarin is considered hardy to 14 ^{o}F (-10 ^{o}C) if properly acclimated to cold and this is the threshold for severe freeze injury (Ebel et al., 2005). The threshold for moderate freeze injury, 18 to 22 ^{o}F (-7.7 to -5.5 ^{o}C) also depends upon adequate cold acclimation prior to the freeze event.

The matrix of severe and moderate freeze probabilities was created from the array of severe freeze and moderate freeze probabilities with 5-percent intervals. The 5-percent interval has the added convenience of equaling 1.0 freeze difference when applied to the 20-year simulation investment horizon, i.e. 5, 10, and 15-percent probabilities equal 1, 2 and 3 freeze events, respectively, in a 20 year period (Table 1). The value of each element in the matrix is the result obtained with freeze probabilities for that particular column and row. The total probability of all freezes (severe and moderate) is found by adding the probabilities for the column and row. Since the zero-percent severe freeze column had no severe freezes, both the Unprotected and the Micro-jet strategies would have the same total number and type of freezes. In the Micro-jet matrix table, the upper right triangle will be a mirror image of the lower left triangle as the effect of both severe and moderate freezes were assumed to be equal in the simulation model; the maximum number of freeze events possible in this matrix was 12 (60-percent total freezes) at the 30-percent severe, 30-percent moderate intersection. For the High Tunnel strategy, the simulation model treated all freezes the same and assumed that no injury occurred from any of the freeze events. All values in the freeze matrix were identical for the High Tunnel strategy and will be reported as a single value.

Table 1. Array of Severe by Moderate Freeze Occurrence

Moderate Freeze -	Severe Freeze - Percent Probability						
% Probability	0	5	10	15	20	25	30
0	0, 0	5, 0	10, 0	15, 0	20, 0	25, 0	30, 0
5	0, 5	5, 5	10, 5	15, 5	20, 5	25, 5	30, 5
10	0, 10	5, 10	10, 10	15, 10	20, 10	25, 10	30, 10
15	0, 15	5, 15	10, 15	15, 15	20, 15	25, 15	30, 15
20	0, 20	5, 20	10, 20	15, 20	20, 20	25, 20	30, 20
25	0, 25	5, 25	10, 25	15, 25	20, 25	25, 25	30, 25
30	0, 30	5, 30	10, 30	15, 30	20, 30	25, 30	30, 30

3.4 Results and Discussion

3.4.1 Net Returns

The discounted 20-year net returns from the simulations of the Unprotected and Micro-jet protected groves are presented in Tables 2 and 3 for all freeze event combinations at three price levels. The values represent the expected return from a 10-acre grove for each scenario using a 6-percent discount factor. It should be noted that the discussion of results for this study will be limited to expected returns and will not consider the distribution of returns. The net return calculation is slightly higher than a Net Present Value (NPV) calculation because the fixed expenses for equipment,

Table 2. Twenty-year Discounted Net Returns[a] for 10-Acre Unprotected Satsuma Grove with Varying Probabilities of Moderate and Severe Freeze Occurrence

Moderate Freeze	Severe Freeze - Percent Probability						
% Probability	0	5	10	15	20	25	30
				Market Price = $0.50/lb			
0	901,076	676,809	500,691	354,093	233,626	135,893	55,590
5	845,124	631,190	460,513	319,933	205,539	112,489	37,277
10	789,260	583,732	421,048	287,279	177,537	89,436	17,193
15	733,154	536,217	382,233	253,748	150,190	65,360	-3,762
20	677,609	489,745	343,004	220,531	121,751	40,414	-22,534
25	622,331	442,108	303,882	187,220	91,959	18,523	-42,708
30	566,189	396,182	264,259	151,772	65,889	-5,133	-62,811
				Market Price = $0.75/lb			
0	1,779,338	1,380,943	1,068,212	808,297	594,649	421,492	279,843
5	1,679,364	1,299,116	996,149	746,686	543,810	379,014	246,377
10	1,579,521	1,214,180	925,203	687,734	493,240	337,133	209,837
15	1,479,315	1,129,030	855,372	627,140	443,724	293,541	171,717
20	1,379,951	1,045,667	784,911	567,436	392,404	248,345	137,505
25	1,280,988	960,421	714,553	507,456	338,624	208,598	100,814
30	1,180,729	878,015	643,444	443,674	291,479	165,752	64,210
				Market Price = $1.00/lb			
0	2,657,599	2,085,065	1,635,734	1,262,501	955,673	707,072	504,172
5	2,513,603	1,967,042	1,531,785	1,173,439	882,082	645,540	455,478
10	2,369,782	1,844,629	1,429,358	1,088,189	808,943	584,829	402,481
15	2,225,476	1,721,842	1,328,511	1,000,979	737,258	521,722	347,196
20	2,082,294	1,601,590	1,226,819	914,342	663,058	456,276	297,543
25	1,939,644	1,478,735	1,125,224	827,692	585,288	398,673	244,336
30	1,795,269	1,359,848	1,022,629	735,577	517,070	336,637	191,231

[a] Discount rate is 6-percent and table values are dollars per 10-acre unit.

Note: Returns for a 10-acre equivalent High Tunnel protected grove are $266,192, $1,140,669, and $2,015,145 for market prices of $0.50, $0.75, and $1.00 per pound, respectively.

irrigation, and freeze protection were amortized over the 20-year investment period according to assumed life expectancy and are not fully realized in the initial year incurred. The High Tunnel strategy net return values did not change in response to either severe or moderate freezes. The discounted net returns for the 10-acre equivalent High Tunnel grove are $266,192, $1,140,669, and $2,015,145 for market prices of $0.50, $0.75, and $1.00, respectively.

In the absence of severe freezes, returns for both Unprotected and Micro-jet groves exhibit a linear response to increasing moderate freeze probability and the returns for Unprotected groves exceeded those for the Micro-jet grove at all moderate freeze probability levels by $75,481. This value is the discounted cost of installing and maintaining the micro-jet freeze protection for the 10-acre grove and is an unnecessary expense. However, at the 5-percent or greater probability levels of severe freeze, net returns for the Micro-jet grove exceeded the net returns for the Unprotected grove at all price levels. The loss due to a severe freeze in an unprotected grove is greater than the loss of the next season's crop; it is also includes the cost of replacing the trees and the lost or reduced production during the re-establishment period. Within a given severe freeze probability level (greater than zero), the magnitude of the difference in net returns between the Unprotected and the Micro-jet groves exhibited an inverse response to moderate freeze probability level; the magnitude of this response also decreased as the probability of severe freeze increased. With an increase in moderate freeze events, there was an increased probability that the Unprotected grove would be in a re-establishment period and have a potential yield less than the Micro-jet grove for the simulation year; the potential difference increased with greater probabilities of severe freezes.

Table 3. Twenty-year Discounted Net Returns[a] for 10-Acre Satsuma Grove with Micro-jet Freeze Protection and Varying Probabilities of Moderate and Severe Freeze Occurrence

Moderate Freeze	Severe Freeze - Percent Probability						
% Probability	0	5	10	15	20	25	30
	Market Price = $0.50/lb						
0	825,595	769,625	713,740	657,410	601,896	546,850	490,691
5	769,644	713,780	657,673	601,957	546,754	490,709	435,567
10	713,780	657,673	602,128	546,805	490,658	435,567	379,628
15	657,673	602,128	546,850	490,724	435,423	379,589	323,913
20	602,128	546,850	490,709	435,423	379,547	323,663	267,822
25	546,850	490,709	435,567	379,547	323,663	267,604	211,579
30	490,709	435,567	379,628	323,913	267,822	211,579	155,932
	Market Price = $0.75/lb						
0	1,703,857	1,603,883	1,503,971	1,403,402	1,304,081	1,205,507	1,105,234
5	1,603,883	1,504,040	1,403,835	1,304,181	1,205,358	1,105,248	1,006,490
10	1,504,040	1,403,835	1,304,471	1,205,444	1,105,182	1,006,490	906,535
15	1,403,835	1,304,471	1,205,507	1,105,248	1,006,262	906,473	806,915
20	1,304,471	1,205,507	1,105,248	1,006,262	906,402	806,475	706,733
25	1,205,507	1,105,248	1,006,490	906,402	806,475	706,346	606,321
30	1,105,248	1,006,490	906,535	806,915	706,733	606,321	506,805
	Market Price = $1.00/lb						
0	2,582,118	2,438,123	2,294,203	2,149,394	2,006,265	1,864,164	1,719,505
5	2,438,123	2,294,301	2,149,996	2,006,405	1,863,962	1,719,788	1,577,412
10	2,294,301	2,149,996	2,006,813	1,864,083	1,719,706	1,577,412	1,433,441
15	2,149,996	2,006,813	1,864,164	1,719,855	1,577,101	1,433,358	1,289,918
20	2,006,813	1,864,164	1,719,788	1,577,101	1,433,257	1,289,287	1,145,643
25	1,864,164	1,719,788	1,577,412	1,433,257	1,289,287	1,145,088	1,001,064
30	1,719,788	1,577,412	1,433,441	1,289,918	1,145,643	1,001,064	857,678

[a] Discount rate is 6-percent and table values are dollars per 10-acre unit.

Note: Returns for a 10-acre equivalent High Tunnel protected grove are $266,192, $1,140,669, and $2,015,145 for market prices of $0.50, $0.75, and $1.00 per pound, respectively.

It is notable that at market prices of $0.50 and higher, the discounted 20-year net returns were significantly positive for all strategies and freeze risk levels except for the highest freeze risk levels for the Unprotected grove. Producers facing severe freeze probability levels greater than 10-percent may do well to consider investment in freeze protection. Whether investment in expensive high tunnels would yield greater net returns to management than the Micro-jet strategy depends on the interaction of expected market price and number of freeze events. The High Tunnel grove had higher net returns at $0.50/lb market price only when more than 10 total freeze events were expected over the 20-year period; as market price increased, however, the effect of greater total fruit yield for the High Tunnel grove decreased this turning point to 5 freeze occurrences at market prices of $0.75/lb and 3 freeze occurrences at market prices of $1.00/lb.

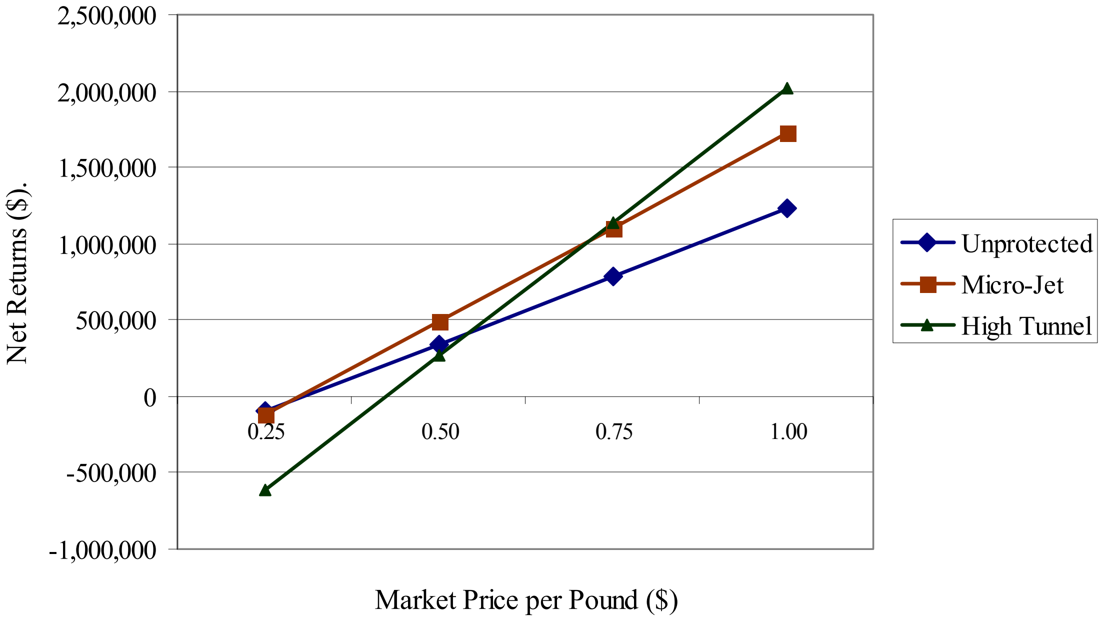

Figure 1. Twenty-Year Discounted Net Returns for Satsuma Groves with 10-percent Probability of Severe freeze and 20-percent Probability of Moderate Freeze

Net returns for all strategies and scenarios exhibit a linear response to market price as illustrated in the example of returns for Satsuma groves with the example of freeze probability levels of 10-percent severe and 20-percent moderate (Figure 1). This linear response allows for the calculation of break-even prices and comparative equivalent prices. Break-even prices occur at the market price where the 20-year net returns equal zero and intersect the market price axis. The equivalent prices are found where two price response lines intersect and are calculated with Equation 2. If the market price is greater than a given equivalent price between two strategies, the strategy with the greatest total yield will have a higher net return. Total fruit yield is a function of freeze event and tree age (Equation 1) and given the assumptions used in the simulations for this study, total yield is highest for the High Tunnel grove. Total yield for the Micro-jet grove exceeds that for the Unprotected grove except in the absence of severe freezes where the yields are equal. Over the freeze probability range used in the simulations, the equivalent prices calculated for the Micro-jet and the High Tunnel technologies closely fit the equation: $y = 12.582\ x^{-0.8311}$, as seen in Figure 2.

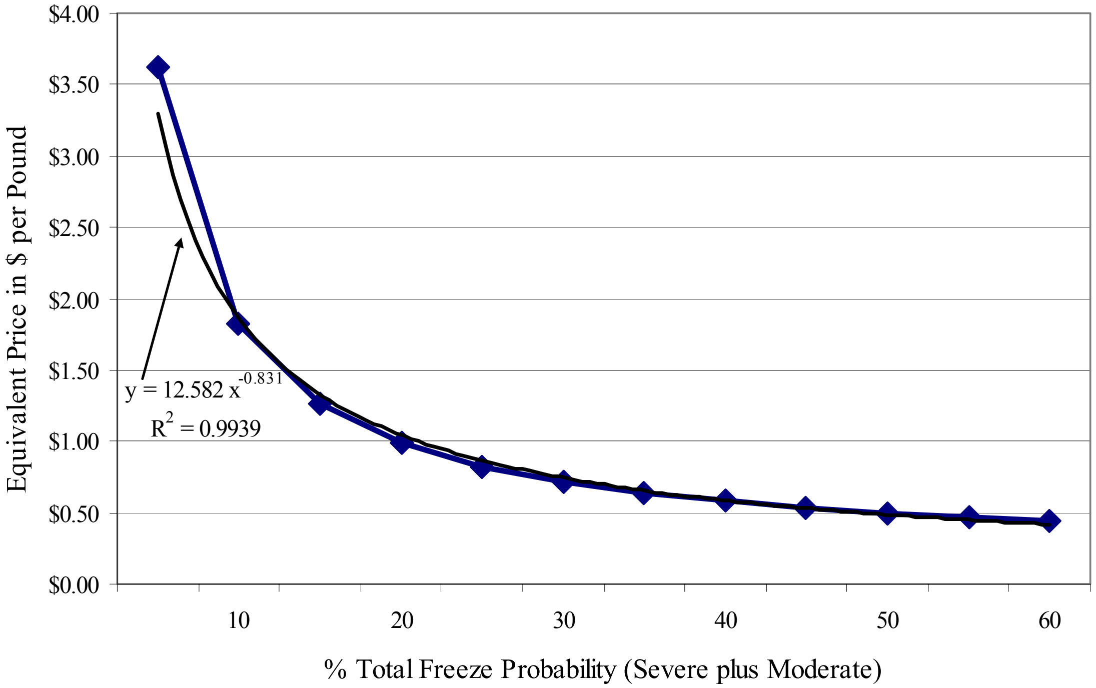

Figure 2. Equivalent Price between Micro-jet and High Tunnel at Freeze Probability Levels of 5-percent to 60-percent (above which High Tunnel has greater net returns)

Table 4. Break-even Prices for Simulations of Satsuma Groves with Different Levels of Freeze Protection and Varying Probabilities of Moderate and Severe Freeze Occurrence

Moderate Freeze	Severe Freeze - Percent Probability						
% Probability	0	5	10	15	20	25	30
	Unprotected Grove - Break-even Prices						
0	0.243	0.260	0.279	0.305	0.338	0.381	0.438
5	0.247	0.264	0.285	0.312	0.348	0.394	0.455
10	0.250	0.269	0.291	0.321	0.359	0.410	0.478
15	0.254	0.274	0.298	0.330	0.372	0.428	0.505
20	0.259	0.280	0.306	0.341	0.388	0.451	0.535
25	0.264	0.287	0.315	0.354	0.407	0.476	0.574
30	0.269	0.294	0.326	0.370	0.427	0.508	0.624
	Micro-jet Grove - Break-even Prices						
0	0.265	0.269	0.274	0.280	0.286	0.292	0.300
5	0.269	0.274	0.280	0.286	0.292	0.300	0.301
10	0.274	0.280	0.286	0.292	0.300	0.309	0.320
15	0.280	0.286	0.292	0.300	0.309	0.320	0.332
20	0.286	0.282	0.300	0.309	0.320	0.332	0.347
25	0.292	0.300	0.309	0.320	0.332	0.347	0.366
30	0.300	0.309	0.320	0.332	0.347	0.366	0.389
	High Tunnel Grove - Break-even Prices						
0	0.424	0.424	0.424	0.424	0.424	0.424	0.424
5	0.424	0.424	0.424	0.424	0.424	0.424	0.424
10	0.424	0.424	0.424	0.424	0.424	0.424	0.424
15	0.424	0.424	0.424	0.424	0.424	0.424	0.424
20	0.424	0.424	0.424	0.424	0.424	0.424	0.424
25	0.424	0.424	0.424	0.424	0.424	0.424	0.424
30	0.424	0.424	0.424	0.424	0.424	0.424	0.424

3.4.2 A Decision Process

Break-even prices and equivalent prices for all freeze probability combinations are presented in Tables 4 and 5, respectively. The break-even prices in Table 4 condense the information presented in Tables 2 and 3 into a form that allows for an easier comparison of the strategies. The simple decision rule is that at any given freeze probability level, the strategy with the lowest break-even price is the most efficient. This rule may work to evaluate the feasibility of a strategy under highly competitive prices; however, it does not consider the effect of increased yield potential of a strategy at market prices higher than the break-even price.

Table 5. Equivalent Prices for Simulations of Satsuma Groves with Different Levels of Freeze Protection and Varying Probabilities of Moderate and Severe Freeze Occurrence

Moderate Freeze	Severe Freeze - Percent Probability						
% Probability	0	5	10	15	20	25	30
	Unprotected to Micro-jet Equivalent Prices						
0	-	0.322	0.261	0.240	0.230	0.225	0.221
5	-	0.331	0.266	0.244	0.234	0.228	0.225
10	-	0.340	0.272	0.249	0.238	0.232	0.229
15	-	0.350	0.278	0.254	0.243	0.237	0.234
20	-	0.361	0.286	0.260	0.248	0.242	0.240
25	-	0.374	0.295	0.267	0.255	0.250	0.247
30	-	0.389	0.305	0.275	0.263	0.258	0.256
	Micro-jet to High Tunnel Equivalent Prices						
0	-	3.629	1.828	1.261	0.987	0.825	0.716
5	3.628	1.829	1.263	0.987	0.825	0.716	0.639
10	1.829	1.263	0.988	0.825	0.716	0.639	0.582
15	1.263	0.988	0.825	0.716	0.639	0.582	0.537
20	0.988	0.825	0.716	0.639	0.582	0.537	0.501
25	0.825	0.716	0.639	0.582	0.537	0.501	0.472
30	0.716	0.639	0.582	0.537	0.501	0.472	0.447
	Unprotected to High Tunnel Equivalent Prices						
0	-	1.103	0.691	0.552	0.484	0.445	0.419
5	4.097	0.942	0.643	0.530	0.472	0.437	0.414
10	2.053	0.825	0.605	0.511	0.460	0.429	0.409
15	1.410	0.740	0.572	0.494	0.450	0.422	0.403
20	1.098	0.675	0.544	0.478	0.440	0.415	0.399
25	0.913	0.623	0.520	0.464	0.431	0.410	0.394
30	0.789	0.583	0.499	0.451	0.423	0.404	0.390

The equivalent price table (Table 5) will allow for the determination of the strategy that yields the highest net return at a given freeze probability combination and market price. The decision rule is to choose the strategy with the highest total crop yield if the market price is greater than the equivalent price. This process assumes that the yield relationship between strategies is Unprotected < Micro-jet < High Tunnel. Care must be taken, however, not to fall below the break-even price. A combination use of the tables would avoid this.

To aid in future development of a computerized decision tool, a decision tree was developed that utilizes information from the break-even table and the equivalent price table. The following proposed decision process requires an assumption of the freeze probability combination and an average market price on the part of the user:

1) Is market price = equivalent price for Unprotected vs. Micro-jet?
    A) Yes – net returns are equal.
    B) No – go to 2)
2) Is market price > equivalent price for Unprotected vs. Micro-jet?
    A) No – Is the market price > break-even price for Unprotected?
        a) No – stop, net return will be negative.
        b) Yes – Unprotected will have the highest expected return.
    B) Yes – Is the market price ≥ equivalent price for Micro-jet vs. High Tunnel?
        a) No – Is the market price > break-even price for Micro-jet?
            (1) No – stop, net return will be negative.
            (2) Yes – Micro-jet will have the highest expected return.
        b) Yes – Is the market price = break-even price for High Tunnel?

        (1) Yes – net returns are equal for Micro-jet and High Tunnel.
        (2) No – Is the market price > break-even price for High Tunnel?
            (a) No – stop, net return will be negative.
            (b) Yes – High Tunnel will have the highest expected return.

C) Don't know (Severe freeze probability = 0)

Is market price ≥ equivalent price for Micro-jet vs. High Tunnel?

- a) No – Is the market price > break-even price for Unprotected?
    - (1) No – stop, net return will be negative.
    - (2) Yes – Unprotected will have the highest expected return.
- b) Yes – Is the market price > equivalent price for Micro-jet vs. High Tunnel?
    - (1) Yes – High Tunnel will have the highest expected return.
    - (2) No– Unprotected will have the highest expected return.

This decision process will always choose the strategy with the highest expected return. Comparison of the strategies will result in the same conclusions as comparing the net returns tables but has the added advantage of showing the market-price break point where one strategy will have higher returns than the other. The decision process may appear cumbersome and a decision maker could look at the tables and come to the same conclusion. If underlying assumptions for the simulations were changed, however, a new set of break-even and equivalent price tables would be produced. Studying many sets of tables would become tedious. The above process would be useful in the programming of a decision tool that allows for changes in underlying cost and yield variables. This decision process was developed for evaluating the Satsuma strategies that were simulated for this study; however, it could easily be adapted to the evaluation of other risk reduction strategies in other crops.

3.5 Conclusions

The purpose of the present study was to evaluate the effect of varying the severe and moderate freeze probabilities on discounted net returns for Satsuma groves with different levels of freeze protection. This information would aid potential producers in evaluating the feasibility of producing Satsuma mandarins in areas with freeze probabilities that vary from those for the Fairhope, AL area. The 20-year discounted net returns were calculated over an array of severe and moderate freeze probability combinations at 5-percent increments ranging from zero to 30-percent. The net returns were determined for Satsuma groves with three different levels of freeze protection.

Only, in the absence of severe freezes do returns for the Unprotected grove exceed returns for the Micro-jet grove. When the probability of severe freeze increases to 5-percent and above, net returns are greater for the Micro-jet grove than the Unprotected Grove at all moderate freeze probabilities and market prices evaluated in the study.

The 20-year total expected fruit yield is a function of freeze event and tree age and increases as the level of freeze protection increases with Unprotected < Micro-jet < High Tunnel. Increasing market prices results in a greater rate of return to the High Tunnel strategy than to the other strategies due to greater total yield over the 20-year period. Net returns are greater for the High Tunnel grove than the Micro-jet grove when total freeze events exceed 10 in the 20-year period at $0.50/lb market price; this also occurs when there are more than 5 freeze occurrences at market prices of $0.75/lb and more than 3 freeze occurrences at market prices of $1.00/lb.

Net returns for all strategies and scenarios exhibit a linear response to market price and this relationship is used to calculate break-even prices for each scenario and equivalent prices between the strategies. Break-even prices occur at the market price where the 20-year net returns equal zero and intersect the market price axis. The equivalent price is the market price where two price response lines intersect and have equal net returns. Evaluation of equivalent prices is a simple method of identifying the strategy with the highest net returns and has the added advantage of identifying the market price at which one strategy will return more than the other will. A decision process based on the break-even and equivalent prices was proposed for future use in programming a computer-based decision tool.

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APPENDIX A: SIMULATION VARIABLES FOR CHAPTER 1

Table A1. Information for Tree and Fruit Crop Insurance Policies Used in Simulations for Chapter 1

		Value per Acre					
	Rate or	Tree Leaf Year					
Item	Unit	1	2	3	4	5	6+
Texas Citrus I Tree Policy[a]:							
Coverage level assumption	65%						
Maximum Reference Amount	$4,190						
Coverage Level x Reference	$2,723						
Liability by Tree Year	percent	33.0	60.0	80.0	90.0	100.0	100.0
Liability by Tree Year	dollar	899	1,634	2,178	2,451	2,723	2,723
Premium	dollar	155	155	155	155	155	155
Arizona-California Citrus Policy[b]:							
Mandarins:							
Coverage level assumption	65%						
Price Election (per 25 lb carton)	$5.70						
T-Yield (25 lb carton per acre)	430						
Yield Adjustment (t-yield x .60)	258						
Total Premium	$0.313	0.00	0.00	0.00	0.00	0.00	Formula[c]
Government Premium Subsidy Rate	59%						
Liability per acre		0.00	0.00	0.00	0.00	0.00	Formula[c]

[a] 2008 Policy with fixed coverage per acre of trees.

[b] 2008 Policy with coverage per acre based on actual production history (APH).

[c] Premium = Liability x base rate; Liability = APH x Coverage Level x Price Election.

Sources: Hinson, et al., Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006.
USDA-RMA, 2008 Policy and Actuarial Documents, www.rma.usda.gov.

Table A2. Fixed and Direct Costs (Excluding Harvest Costs) per Acre of Satsuma Used in Simulations for Chapter 1

		Quantity of Unit per Acre						Cost of Item per Acre[a]				
		Tree Leaf Year						Tree Leaf Year				
Item	Unit	1	2	3	4	5+	Rate	1	2	3	4	5+
Fertilizer												
13-13-13	cwt	2.00	6.00	3.00	8.00	10.00	15.50	31.00	93.00	46.50	124.00	155.00
Amm Nitrate (34%)	cwt			1.00	1.20	1.50	16.00			16.00	19.20	24.00
Fungicide	dollar	18.94	0	172.53	214.30	228.79	1.00	18.94		172.53	214.30	228.79
Herbicide	dollar	40.00	219.68	126.00	136.00	136.00	1.00	40.00	219.68	126.00	136.00	136.00
Insecticide	dollar	32.30	40.73	69.94	192.16	190.82	1.00	32.30	40.73	69.94	192.16	190.82
Trees	each	116.00	10.00				8.00	928.00	80.00			
Labor												
Mark Rows	hour	4.00					9.60	38.40				
Plant	hour	20.00	3.00				9.60	192.00	28.80			
Nutrients	hour	5.00	8.00	7.00			9.60	48.00	76.80	67.20		
Prune	hour	4.50	4.00	5.00	1.50	6.50	9.60	43.20	38.40	48.00	14.40	62.40
Strip Fruit	hour		1.00				9.60		9.60			
Scout	hour		5.00	6.00	18.00	20.00	9.60		48.00	57.60	172.80	192.00
Operator	hour	16.84	10.40	13.16	11.79	11.45	15.30	257.65	159.12	201.35	180.39	175.19
Diesel Fuel	gal	39.21	18.79	24.19	29.30	28.53	2.23	87.44	41.90	53.94	65.34	63.62
Gasoline	gal	0.90	1.80	2.10			2.63	2.37	4.73	5.52		
Repair & Maint	dollar	60.54	37.37	45.51	56.02	54.47	1.00	60.54	37.37	45.51	56.02	54.47
Interest on Op Capital	dollar	87.49	40.78	58.87	83.61	99.02	1.00	87.49	40.78	58.87	83.61	99.02
Fixed												
Implements	dollar	38.64	23.13	29.48	73.92	72.37	1.00	38.64	23.13	29.48	73.92	72.37
Tractor	dollar	47.45	22.89	29.89	36.43	35.40	1.00	47.45	22.89	29.89	36.43	35.40
Self-Propelled	dollar	4.65	9.30	10.85	0.00	0.00	1.00	4.65	9.30	10.85	0.00	0.00
Packing Line	dollar			141.02	141.02	141.02	1.00			141.02	141.02	141.02
Total Direct and Fixed								1958.07	974.24	1180.20	1509.59	1630.10

[a] For each tree leaf year: Cost of Item per Acre = Quantity of Unit per Acre x Rate.

Source: Hinson, et al., Projected Costs of Establishing and Operating a Citrus Grove. Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006.

Table A3. Fixed and Direct Costs per Acre of Satsuma and Variables Used in Simulations for Chapter 1

		Quantity of Unit per Acre						Cost of Item per Acre[a]				
		Tree Leaf Year						Tree Leaf Year				
Item	Unit	1	2	3	4	5+	Rate	1	2	3	4	5+
Direct Costs:												
Harvest Aid												
Field Box	each			10.0	10.0	10.0	12.00			120.00	120.00	120.00
Harvest Container	each			10.0	10.0	10.0	2.00			20.00	20.00	20.00
Electricity - Pack Line	kwh			175.0	175.0	210.0	0.12			21.00	21.00	25.20
Repair & Maint - Pack Line	dollar			50.00	50.00	50.00	1.00			50.00	50.00	50.00
Total Harvest Direct Costs								0.00	0.00	211.00	211.00	215.20
Variable Costs[b]:												
Harvest Labor - per Bushel							2.25					
Grading Labor - per Bushel							2.90					
Marketing Box - Bushel							1.25					
Total Variable Cost per Bushel							6.40					
(Note: Bushel = 40 lb)												
Micro-Sprinkler Freeze Protection:							Life					
Amoritization Rate	6%											
Well, pump, pipes	6,000						20 yr	523.08	523.08	523.08	523.08	523.08
Below ground pipes	350						20 yr	30.51	30.51	30.51	30.51	30.51
Tubing, emitters	185						4 yr	53.39	53.39	53.39	53.39	53.39
Annual Maintenance	$25							25.00	25.00	25.00	25.00	25.00

[a] For each tree leaf year: Cost of Item per Acre = Quantity of Unit per Acre x Rate.

[b] Harvest costs are not incurred if a freeze occurs in the simulation.

Sources: Hinson, et al., Projected Costs of Establishing and Operating a Citrus Grove. Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006. Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama.

APPENDIX B: SIMULATION VARIABLES FOR CHAPTERS 2 AND 3

Table B1. Yield and Establishment Cost Variables used in Simulations for Chapter 2 and Chapter 3

			Leaf Year									
	Strategy[a]	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**	**Rate**
Revenue												
Yield/Tree - Conventional	UP, MJ	lb/tree	0	0	70	120	190	250	350	350	400	$0.25
Yield/Tree - Conventional	UP, MJ	bu/ac	0	0	203	348	551	725	1015	1015	1160	$10.00
Yield/Tree - High Density	HT	lb/tree	0	0	35	60	95	125	175	175	200	$0.25
Yield/Tree - High Density	HT	bu/ac equiv	0	0	202	347	549	722	1011	1011	1155	$10.00
(Note: 1 bu = 40 lb)												
Establishment Cost												
Land Preparation	All	$/ac, ac equiv	100									1.00
Conventional Spacing:												
Plants	UP, MJ	no./ac	116	12								$8.00
Labor - layout & plant	UP, MJ	hour/ac	24	3								$9.60
Labor - Strip fruit	UP, MJ	hour/ac		1								$9.60
High Density Planting:												
Plants/ac equivalent[b]	HT	no./ac equiv	231	23								$8.00
Labor - layout & plant	HT	hour/ac equiv	48	6								$9.60
Labor - Strip fruit	HT	hour/ac equiv		2								$9.60

[a] UP = Unprotected grove, MJ = Micro-jet grove, HT = High Tunnel grove.

[b] Plants/ac equivalent changes with yield ratio: 1.5 = 174 plants, 2.0 = 231 plants, 2.5 = 291 plants, and 3.0 = 348 plants.

Sources: Hinson, et al., Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006. Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama.

Table B2. Direct and Variable Cost Variables used in Simulations for Chapter 2 and Chapter 3

			Leaf Year									
	Strategy[a]	**Unit**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9+**	**Rate**
Direct Costs												
Pest/Disease/Weed	UP, MJ	$/acre	91.24	260.41	368.47	542.46	555.61	555.61	555.61	555.61	555.61	1.00
Pest/Disease - High Tunnel	HT	$/acre equiv	91.24	40.32	242.47	406.46	419.61	419.61	419.61	419.61	419.61	1.00
High Tunnel Plastic	HT	$/tunnel	164	164	164	164	164	164	164	164	164	7.70
Fertilize (13-13-13)	All	cwt/ac, ac equiv	2	6	4	9.2	11.5	11.5	11.5	11.5	11.5	$15.50
Fuel (diesel & gas)	All	gal/ac, ac equiv	40	20.6	26.3	29.3	28.5	28.5	28.5	28.5	28.5	$2.23
Repair/maintenance	All	$/ac, ac equiv	60.00	38.00	45.00	55.00	55.00	55.00	55.00	55.00	55.00	1.00
Operator Labor	All	hour/ac, ac equiv	16.8	10.4	13.2	11.8	11.45	11.45	11.45	11.45	11.45	$15.30
Labor:												
Prune - Conventional	UP, MJ	hour/ac	4.5	4	5	1.5	6.5	6.5	6.5	6.5	6.5	$9.60
Prune - High Density	HT	hour/ac equiv	9	8	10	3	13	13	13	13	13	$9.60
Fertilize	All	hour/ac, ac equiv	5	8	7	7	7	7	7	7	7	$9.60
Scouting	All	hour/ac, ac equiv		5	6	18	20	20	20	20	20	$9.60
Micro-jet Maintenance	MJ	hour/ac	3	3	3	3	3	3	3	3	3	$9.60
High Tunnel Maint	HT	hour/ac equiv	2	12	12	12	12	12	12	12	12	$9.60
Irrigation Maint	All	hour/ac, ac equiv	10	10	10	10	10	10	10	10	10	$9.60
Harvest Variable Costs												
Field Boxes	All	no./ac, ac equiv			50	10	10	10	10	10	10	$12.00
Harvest Labor	All	bu/ac, ac equiv			203	348	551	725	1015	1015	1160	$2.25
Pack - Box	All	bu/ac, ac equiv			203	348	551	725	1015	1015	1160	$1.25
Grad & Pack - Labor	All	hour/ac, ac equiv			68	116	184	242	338	338	387	$9.60
Pack line electricity	All	kwh/ac, ac equiv			175	175	200	259	338	338	387	$0.12
Pack line repair/maint	All	$/ac, ac equiv			50	50	50	50	50	50	50	1.00
Interest on Operating Cap	All	$/ac										$0.048

[a] UP = Unprotected grove, MJ = Micro-jet grove, HT = High Tunnel grove.

Sources: Hinson, et al., Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006. Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama.

Table B3. Fixed Cost Variables used in Simulations for Chapter 2 and Chapter 3

			Leaf Year							Amortization
	Strategy[a]	Unit	1	2	3	4+	Rate	Cost	Life	Factor
								($)	(Year)	(6%)
Fixed Costs										
Tractors & equipment	All	$/ac, ac equiv	90.75	55.00	70.00	110.00	1.00			
Pack line	All	$/ac, ac equiv	191.58	191.58	191.58	191.58	1.00	1,410	10	0.13587
Irrigation	All	$/ac, ac equiv	87.18	87.18	87.18	87.18	1.00	1,000	20	0.08718
<u>Freeze Protection</u>										
Well, pump, pipes	MJ	$/acre	553.59	553.59	553.59	553.59	1.00	6,350	20	0.08718
Tubing, emitters	MJ	$/acre	53.39	53.39	53.39	53.39	1.00	185	4	0.28859
Installation Labor	MJ	$/acre	25				$9.60			
<u>High Tunnel</u>										
Structure	HT	$/tunnel	392.33	392.33	392.33	392.33	1.00	4,500	20	0.08718
Installation Labor	HT	hour/ac equiv	40				$9.60			

[a] UP = Unprotected grove, MJ = Micro-jet grove, HT = High Tunnel grove.

Sources: Hinson, et al., Louisiana Agri. Expt. Sta. Info. Series No. 140, 2006. Alabama Agricultural Experiment Station Gulf Coast Research and Extension Center at Fairhope, Alabama.